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Research Document 2012/104 | **Document de recherche 2012/104**

Gulf Region | **Région du Golfe**

Assessment of Atlantic Salmon (*Salmo salar*) in Salmon Fishing Area 16 of the southern Gulf of St. Lawrence

Évaluation du Saumon atlantique (*Salmo salar*) de la Zone de Pêche au Saumon 16 du sud du golfe du Saint-Laurent

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ISSN 1499-3848 (Printed / Imprimé)
ISSN 1919-5044 (Online / En ligne)
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Correct citation for this publication:
La présente publication doit être citée comme suit :

Douglas, S.G., Chaput, G., Hayward, J., and Sheasgreen, J. 2013. Assessment of Atlantic Salmon (*Salmo salar*) in Salmon Fishing Area 16 of the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/104. v + 63 p.

ABSTRACT

Of the 39 Atlantic salmon rivers in Salmon Fishing Area 16, the Miramichi River is the largest and accounts for over 90% of the juvenile rearing habitat in SFA 16. Annual returns of adult salmon to the Miramichi River were monitored at estuarial trapnets and their abundance estimated with a mark and recapture experiment. The proportion of the conservation requirement attained was determined after accounting for the number of large (≥63 cm) and small (<63 cm) salmon harvested and lost from aboriginal and recreational fisheries. In 2011, returns of Atlantic salmon to the Miramichi River were estimated at 34,090 large salmon and 45,880 small salmon. The large salmon return in 2011 was among the highest return estimates since 1970 and the small salmon return was equivalent to the highest estimates since 1994. Returns of large and small salmon to the Southwest Miramichi River in 2011 were 27,870 (5th and 95th percentiles 17,140-58,150) and 31,710 (22,360-45,890) and enough to exceed the egg conservation requirement before fisheries (220%) and after accounting for removals from fisheries (212%). Similarly for the Northwest Miramichi River, the returns of large and small salmon were 5,147 (3,180-8,813) and 13,550 (9,976-18,680) and adequate to exceed the egg conservation requirement before (132%) and after fisheries' removals (109%). Catches and counts of large and small salmon at provincial barriers and crown reserve angling stretches in 2011 were the highest or among the highest of the 28-year time series (1984-2011). The biological characteristics of adult salmon sampled at DFO index trapnets in the Miramichi River were updated for 2011 and the progressive change in run-timing from a dominant late-run to a dominant early-run over the last decade was presented. Salmon with wounds ranging from minor scratches to deep lacerations have been observed at DFO monitoring facilities in recent years but the cause remains unknown. Salmon destined for rivers of SFA 16 were intercepted in the mackerel drift gillnet fishery off of the coast of Prince Edward Island in June 2011 but the total mortality or effects on stocks is unknown. Juvenile salmon were sampled throughout the Miramichi watershed in 2011 and have remained at consistent levels since 1984 when significant changes in the management of the commercial and recreational salmon fisheries occurred. Estuarial trapnetting programs and electrofishishing surveys conducted by several First Nations, watershed associations, and the DFO indicate that adult salmon continue to spawn annually in other SFA 16 rivers (Tabusintac, Buctouche, Richibucto, and Kouchibouguacis) but estimates of adult returns have not been possible for several years. Reliable catch and harvest information from the recreational and aboriginal fisheries remain a significant constraint to the assessment of Atlantic salmon in SFA 16 and precludes any rigorous evaluation of current or potentially new management scenarios for these stocks.

RÉSUMÉ

La zone de pêche au saumon (ZPS) 16 comprend 39 rivières à saumon atlantique dont la rivière Miramichi qui est la plus grande et qui contient 90% de la surface totale d'habitat propice à l'élevage de juvéniles de cette zone. Les retours annuels en rivière de saumons adultes à la rivière Miramichi sont évalués par des suivis de captures dans des filets-trappes posés dans les estuaires. L'abondance des adultes est estimée en utilisant des expériences de marquages et de recaptures. La proportion des besoins en matière de conservation atteinte est évaluée après avoir comptabilisé les pertes de petits saumons (longueur à la fourche < 63 cm) et des grands saumons (longueur à la fourche >= 63 cm) dans les pêches autochtones et récréatives. En 2011 les retours en rivière de saumon de la rivière Miramichi ont été évalués à 34 090 grands saumons et 45 880 petits saumons. Les retours en rivière de grands saumons en 2011 étaient parmi les plus importants depuis 1970 tandis que les retours de petits saumons en 2011 étaient de la même ordre de grandeur que les plus importants niveaux depuis 1994. Les retours de saumons dans la rivière Miramichi Sud-ouest en 2011 ont été évalués à 27 870 (écart du 5^{ie} au 95^{ie} percentiles de 17 140 à 58 150) grands saumons et 31 710 (écart du 5^{ie} au 95^{ie} percentiles de 22 360 à 45 890) petits saumons. Les pourcentages des besoins en matière de conservation étaient de 220% avant les pertes dans les pêcheries et de 212% après les pertes de petits saumons et de grands saumons dans les pêcheries. Pour la rivière Miramichi Nord-ouest, les retours de saumons en 2011 ont été évalués à 5 147 (écart du 5^{ie} au 95^{ie} percentiles de 3 180 à 8 813) grands saumons et 13 550 (écart du 5^{ie} au 95^{ie} percentiles de 9 976 à 18 680) petits saumons. Les pourcentages des besoins en matière de conservation étaient de 132% avant les pertes dans les pêcheries et de 109% après les pertes de petits saumons et de grands saumons dans les pêcheries. En 2011, les captures dans la pêche récréative des eaux de la Couronne de la rivière Miramichi Nord-ouest et les décomptes de saumons aux barrières provinciales de rétention étaient les plus hauts ou presque plus hauts de la série temporelle de 1984 à 2011. Les caractéristiques biologiques des saumons adultes de la rivière Miramichi provenant des captures aux filets-trappes du MPO sont mises à jour. On note un changement progressif durant la dernière décennie dans le synchronisme saisonnier de la migration des saumons, passant d'une population avec une migration dominante d'automne à une migration plus hâtive et dominante d'été. Bon nombre de saumons avec des blessures représentées par des égratignures superficielles jusqu'à des lacérations profondes ont été observés ces dernières années aux sites de suivis du MPO mais les causes de ces blessures sont inconnues. Des saumons migrant vers les rivières de la ZPS 16 ont été interceptés dans les filets maillants dérivants de la pêche au maquereau au nord de l'Île-du-Prince-Édouard en juin 2011 mais la mortalité totale attribuable à ces interceptions et les conséquences sur les stocks sont inconnues. Des juvéniles de saumon ont été échantillonnés à travers le bassin versant de la Miramichi durant 2011. Les abondances relatives des juvéniles sont demeurées similaires aux niveaux depuis 1984 lorsque des mesures restrictives de gestion des pêches commerciales et récréatives ont été imposées. Des activités de suivis avec des filets-trappes en estuaires et par la pêche électrique entreprises pas les groupes autochtones, les associations de bassin versant, and par le MPO démontrent que le saumon frai annuellement dans nombre rivières de la ZPS 16 (Tabusintac, Bouctouche, Richibuctou, et Kouchibouguacis) mais les estimations d'abondance absolue des retours d'adultes n'ont pas été disponibles pendant plusieurs années. L'absence de données fiables des captures et des prélèvements des pêches récréatives et autochtones est la plus importante lacune de l'évaluation du saumon atlantique de la ZPS 16. En outre, cette lacune empêche l'évaluation rigoureuse des conséquences sur les stocks de saumons des mesures de gestion présentement en vigueur ou proposées.

INTRODUCTION

The Atlantic salmon fishing area (SFA) 16 is located along the east coast of New Brunswick and drains the province's rivers that flow east and into the Gulf of St. Lawrence (Fig. 1). Atlantic salmon inhabit 39 rivers of SFA 16 which combine for over 61 million m^2 of juvenile rearing habitat (Amiro 1983). The Miramichi River including its two branches, the Southwest (SW) and Northwest (NW) Miramichi rivers and their enormous network of tributaries account for approximately 91% (55 million m^2) of the juvenile rearing capacity in SFA 16. The remainder of the habitat is found in a number of smaller rivers located primarily in southeastern New Brunswick; sub-management unit SFA 16B (Fig. 1).

While commercial fisheries for Atlantic salmon have remained closed since 1984, Aboriginal peoples and anglers continue to exploit the resource for food and/or recreation. Aboriginal fisheries are managed by communal licenses for food, social, and ceremonial (FSC) purposes with restrictions on gear, season, and seasonal allocations of both small (fork length < 63 cm) and large (fork length ≥ 63 cm) salmon. The recreational fishery is regulated by season and both daily and seasonal bag limits for small salmon; all large salmon must be returned to the water. Due to low spawning escapements, rivers in southeastern NB (SFA 16B) have been closed to recreational angling and aboriginal access since 1998.

An annual monitoring program for adult Atlantic salmon in the Miramichi River has lent itself to regular assessments of the stock since 1982 (Randall and Chadwick 1983a, b; Randall and Schofield 1987, 1988; Randall et al. 1985, 1986, 1989, 1990; Moore et al. 1991, 1992 Courtney et al. 1993; Chaput et al. 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2006, 2010; Chaput 2010). Electrofishing surveys of the Miramichi watershed since 1968 (Moore and Chaput 2007) have helped inform the status of the stock and there has been recent interest to evaluate run sizes of emigrating Atlantic salmon smolts (Chaput et al. 2002). Programs that monitored adult Atlantic salmon in the smaller rivers of SFA 16 have been less frequent and irregular, however juvenile surveys have frequently been undertaken, although not annually in most cases, since the late 1990s.

The objective of the current assessment is to update the status of salmon stocks from SFA 16 with new information collected since their last collective review (Chaput et al. 2010). The current Integrated Management Plan for Atlantic salmon (DFO 2008) will expire at the end of 2012 and fisheries managers have requested an update of the resource to help guide the development of a new management plan. Finally, an updated salmon assessment of SFA 16 will help inform the decision on a listing recommendation for the Gaspé-southern Gulf of St. Lawrence Designatable Unit of Atlantic salmon which has been assessed by COSEWIC as Special Concern (COSEWIC 2010).

FISHERIES

Due to low spawning escapements, rivers in southeastern New Brunswick (SFA 16B) have been closed to all recreational and aboriginal salmon fisheries since 1998.

ABORIGINAL

Aboriginal fisheries for Atlantic salmon are managed under communal licenses with restrictions on gear, location, season, and allocations of both small and large salmon. The majority of aboriginal food, social and ceremonial (FSC) fisheries in SFA 16 occur in estuaries but also

occur in Miramichi Bay and the crown open waters of the Miramichi, Bartibog, and Tabusintac rivers (Table 1). Estuarial trapnet programs with the objective of harvesting salmon for FSC purposes as well as marking and/or recapturing salmon for the purpose of estimating run size exist in the Tabusintac, and the Southwest and Northwest Miramichi rivers, and are conducted by Esgenoôpetitj, Eel Ground, and Metepenagiag First Nations, respectively. Trapnet catch information is provided in each of these cases and makes a valuable contribution to the overall salmon assessment of the Miramichi system. First Nation FSC gillnet fisheries and Native recreational fisheries for Atlantic salmon also occur in these rivers but catch information is incomplete (Table 1).

RECREATIONAL

The recreational fishery is regulated by season and both daily and seasonal bag limits for small salmon. Angling seasons vary slightly throughout SFA 16 but typically open on April 15 and close on October 15. Only the retention of small salmon is permitted in the recreational fishery of SFA 16 and limited to one per day and a maximum of eight for the season. During the bright salmon season (generally May 16 to October 15), angling for Atlantic salmon must cease for the day once the daily bag limit has been filled or four salmon of any size have been captured and released. The same daily bag limit applies to the kelt fishery (April 15 to May 15) but 10 salmon of any size can be captured and released per day (*Gulf Region Close Time and Quota Variation Order 2011-083)*. The upper portions of the Miramichi system close or switch to catch and release during the fall period. Recent concerns about low spawning escapements has prompted a change to catch and release of small salmon in the mid and upper sections of the Northwest Miramichi River in 2011 and is expected to remain that way for the 2012 and 2013 angling seasons.

A creel survey form is provided with the 15 to 20 thousand salmon angling licenses sold annually in the province of New Brunswick (Fig. 2). The rate of return for the creel forms is low and has averaged 215 (range 115-411) in each year between 2008 and 2011, the equivalent of less than 1% of salmon licenses sold in the province for those years (C. Connell, NB DNR pers. comm.). The low return rates of creel forms makes meaningful analysis of catch statistics difficult.

Angling statistics from the Regular Crown Reserve Waters of the Northwest Miramichi River are compiled annually by the NB Department of Natural Resources (DNR) and have been used as an index of salmon abundance in the Northwest Miramichi since 1973 (discussed in detail below).

In conjunction with the Canadian provinces, the DFO conducts a National angler survey every five years. In New Brunswick, 4,500 surveys were completed for the 2010 angling season and were summarized by Recreational Fishing Area. The estimated number of Atlantic salmon caught and harvested in the Miramichi and Southeast Recreational Fishing Areas in 2010 are relevant to SFA 16. The catch and harvest of salmon in the table below includes kelts, bright fish, and those that were caught and released multiple times. There has been no salmon angling season in the Southeast RFA since 1998 so the catch and harvested salmon reported for this area in 2010 are considered to be a consequence of small reporting errors that were inflated with the scaling up process.

	Caught	Harvested
Miramichi Recreational Fishing Area		
Resident	44,898	10,525
Canadian non-resident	2,253	185
Other non-resident	15,562	584
Total	62,983	11,294
Southeast Recreational Fishing Area		
Resident	432	216
Canadian non-resident	-	-
Other non-resident	-	-
Total	432	216

DFO 2010 National Angler Survey (in prep); information provided by C. Connell, NB Department of Natural Resources

ATLANTIC SALMON ADULT RETURNS TO SFA 16

TABUSINTAC RIVER

The estimated spawning requirement for the Tabusintac River is approximately 2.0 million eggs; the equivalent of about 329 large and 175 small salmon (Douglas and Swasson 2000). Esgenoôpetitj First Nation has operated a trapnet program in the Tabusintac River almost annually between 1993 and 2011. The objective of the program is to harvest salmon for food and to provide the basis for a mark and recapture experiment which is used to evaluate the size of the spawning run. In general, salmon have been tagged and released from a lower estuary trapnet and recaptured at an upper estuary trapnet. Any fish harvested for food generally occurs from the upper trapnet. Formal salmon assessments for the Tabusintac River have only occurred for the years 1993, 1994, 1996, 1998, and 1999 and it was determined that conservation had been achieved in each of those years (Table 2; Douglas and Swasson 2000). While the trapnet program has continued since the last assessment, the mark and recapture information has not been adequate to evaluate run size (Table 2). The trapnet information indicates however that both large and small salmon continue to spawn annually in the Tabusintac River.

BUCTOUCHE RIVER

The estimated spawning requirement for the Buctouche River is approximately 1.6 million eggs; the equivalent of about 280 large and 157 small salmon (Atkinson and Peters 2001). Since adult salmon data are not available for other southeast New Brunswick rivers, the Buctouche River has been considered an index river for this area (Atkinson and Peters 2001). The Buctouche First Nation has operated a trapnet program in the Buctouche River almost annually since 1992 (Table 2). Since the closure of all salmon fisheries in SFA16B in 1998, the program has been devoted to collecting biological information and assessing the status of the stock. Salmon returns to the Buctouche River were assessed each year between 1992 and 2000 and the conservation requirement was only met once (1999). While the trapnet program has continued since the last assessment, mark and recapture experiments have not been performed and abundance estimates were not derived. The trapnet information indicates that both large and small salmon continue to spawn annually in the Buctouche River.

RICHIBUCTO RIVER

The estimated spawning requirement for the main stem of the Richibucto River is 135 large and 79 small salmon while 2.9 million eggs (519 large and 303 small salmon) are required for the entire Richibucto system (Atkinson and Cormier 1998). In conjunction with the First Nations of Elsipogtog and Indian Island, and the Richibucto River Association, the adult salmon returns to the Richibucto River were assessed in 1992, 1993, 1994, and 1997. A variety of assessment techniques were used but generally consisted of a mark-recapture experiment between two estuarial trapnets and/or a counting fence at a headwater location, and angling information. Estimates of salmon abundance were possible in 1992 and 1997 but levels were not sufficient to meet the conservation requirement in either year (Table 2). Low numbers of recaptured fish in 1993 and 1994 precluded any estimates of salmon abundance but other indicators suggested that conservation was not met in either of those years. Since 2005, Elsipogtog First Nation, in collaboration with Kouchibouguac National Park, has operated a trapnet in the estuary of the Richibucto River and a second one in the Coal Branch River. While abundance estimates have not been derived from this program, catches indicate that both large and small salmon continue to spawn annually in the Richibucto and Coal Branch rivers. Recent efforts to supplement the natural production of salmon in the Richibucto River by collecting broodstock and stocking adipose clipped fall fingerlings in 2005 and 2006 and unfed fry in 2010 were undertaken by Elsipogtog First Nation.

KOUCHIBOUGUACIS RIVER

The estimated spawning requirement for the Kouchibouguacis River is approximately 1.3 million eggs; the equivalent of about 260 large and 150 small salmon (Chaput et al. 2010). In an attempt to evaluate the run size of salmon to this river, a local watershed group, Les Amies de la Kouchibouguacis, has operated two box-nets in the estuary each year since 2005 (Table 2). While a number of tags were applied in each year, the number of recaptures was small and estimates of run size were not possible. Efforts to supplement the natural production of salmon in the Kouchibouguacis River have resulted in the collection of broodstock and subsequent stocking of unfed fry and fall fingerlings between 2004 and 2011. There continues to be an annual wild run of large and small salmon to this river.

MIRAMICHI RIVER

Indices of Abundance

Mark and recapture experiments

Small and large adult salmon returns to the Miramichi River and its two major branches have been estimated with mark-recapture experiments since 1992. Returning salmon are captured in estuarial trapnets, tagged with individually numbered dorsal tags and released for possible recapture in another trapnet higher in the estuary or one located in the other major branch. Tags are applied to returning grilse and salmon at four trapnet locations during the May to October spawning migration. The tagging locations are two trapnets operated by Eel Ground First Nation on the SW Miramichi River near its confluence with the NW Miramichi River, the DFO index trapnet at Millerton on the SW Miramichi River, and the DFO index trapnet at Cassilis on the NW Miramichi River (Fig. 3). Both DFO index trapnets function as a recapture location for tags applied in the opposite branch, and the two trapnets operated by Red Bank First Nation function as a recapture location for tags applied anywhere. Information on biological characteristics is

derived from samples taken at DFO index trapnets. Descriptions of trapnets, fish processing protocols and treatment of data have been detailed in Chaput (2010).

Protection barriers and Crown reserve angling

Other indices of abundance that have been regularly used to inform the status of Miramichi salmon are counts of large and small salmon at provincial and private headwater protection barriers, as well as, a creel survey from the Regular Crown Reserve waters of the Northwest Miramichi watershed. A headwater protection barrier has been operated by the province of New Brunswick on the NW Miramichi River since 1988 and on the Dungarvon River since 1981. The barrier on the north branch of the Southwest Miramichi River near Juniper has been operated since 1981 but only as a partial fence in recent years (2010 and 2011). Atlantic salmon and brook trout are counted through a lower fence and into a large holding pool until water levels increase in the fall and protection is no longer deemed necessary. Once the barriers are removed in the fall, salmon and trout seek suitable spawning locations in the area.

A creel survey including catch and effort of salmonids is required of anglers using the Regular Crown Reserve stretches of the Northwest Miramichi watershed. Most stretches are open to four rods during a 48 hour period that begins at 2 pm on day one and ends at 2 pm on day three. Crown reserve stretches are available to anglers between June 10 and September 15.

Estimated Returns

Mark and recapture experiments

Estimates of returns to the Miramichi River overall and to its Northwest and Southwest branches between 1998 and 2011 have been derived from a Bayesian hierarchical framework (Table 3, Fig. 4) (Chaput and Douglas 2012). Several variations of the model were explored and the one which incorporates the NW Miramichi and Dungarvon barrier information as an index of early run, and the Juniper barrier information as an index of total returns appears to be the most appropriate treatment of the data (Chaput and Douglas 2012). This is a different variation on the model that was used to derive estimates of salmon returns to the Miramichi River in the last assessment (Chaput 2010). The variation of the model in Chaput and Douglas (2012) is believed to be better because it formalizes the relationship between trapnet catches and barrier counts and will permit using the barrier information to inform past and or future estimates when mark recapture information was or may be poor.

Median estimates of returns of large and small salmon to the Miramichi River overall in 2011 were 34,090 (5^{th} and 95^{th} percentile: 23,010 to 63,610) and 45,880 (5^{th} and 95^{th} percentile 35,750 to 59,390), respectively (Table 3) (Chaput and Douglas 2012). The large salmon return in 2011 was among the highest return estimates since 1970. Small salmon returns in 2011 were lower than in 2010 but equivalent to the highest estimates since 1994.

The returns of large salmon to the Southwest Miramichi in 2011 were estimated at 27,870 (5^{th} and 95^{th} percentile 17,140 to 58,150), which was the highest since 1992 and when separate branch estimates began. The return estimate of 31,710 (5^{th} and 95^{th} percentile 22,360 to 45,890) small salmon to the Southwest Miramichi in 2011 was lower than in 2010 but equivalent to the highest return estimates since 1994 (Table 3).

Northwest Miramichi returns of large salmon in 2011 were estimated at 5,147 fish (5^{th} and 95^{th} percentile 3,180 to 8,813), an improvement over returns estimated during the preceding nine

years but not as high as the 10-15 thousand large salmon return estimates in the early 1990s. The estimated return of small salmon to the NW Miramichi River in 2011 was 13,550 (5th and 95th percentile 9,976 to 18,680), down from 2010 but equivalent to highest levels estimated since 1997 (Table 3).

There is important exchange of salmon between the branches of the Miramichi in tidal waters, particularly for large salmon. Annual rates of exchange for small and large salmon tagged at each of the marking facilities in the Miramichi system have been calculated for the period 1998-2011 (Table 4) (Chaput and Douglas 2012). On average, 83% (range 0.81-0.86) of small and 88% (range 0.82-0.94) of large salmon tagged at trapnets operated by Eel Ground First Nation on the SW Miramichi River remain in that branch. Higher proportions of small (94% range 0.90-0.96) and large (94% range 0.91-0.97) salmon tagged at Millerton on the SW Miramichi River remain in the same branch. The majority (84% range 0.80-0.88) of small salmon tagged at Cassilis on the NW Miramichi River remain in the branch while only 66% (range 0.54-0.76) of large salmon do. The high rate of movement between the major branches was observed in 2011 with multiple recaptures at the Millerton trapnet of both small and large salmon tagged at the Cassilis trapnet (Table 5). Further evidence of movement between the branches comes from angler tag returns. Of particular interest is the number of tags returned during the kelt fishery on the SW Miramichi River that were initially placed in the preceding year at Cassilis on the NW Miramichi River (Table 6).

Biological characteristics

The sex of large salmon can be determined from external features throughout the full spawning migration to the Miramichi River. Combined catches from both DFO index trapnets indicated that the majority (88%) of the large salmon return to the Miramichi River in 2011 was female (1,090 of 1,234). The proportion of large female salmon captured at Cassilis on the NW Miramichi was 91%, the highest proportion of the time series (1998-2011). Similarly, the female component of large salmon captured at Millerton on the SW Miramichi was 86% and the second highest observed since 1994 (Fig. 5).

It is more difficult to determine the sex of small salmon using external features during the early part of the run, before the kype develops on the males later in August and September. Internal examination of harvested small salmon from trapnets operated by Metepenagiag First Nation helped inform the sex ratio of small salmon returning to the NW Miramichi River. In 2011, the proportion of female small salmon returning to the NW Miramichi River was considered to be 35%. Unlike previous assessments, this approach was used to estimate the female grilse proportions returning to the NW Miramichi River between the 1998 to 2010 period. In years when trapnets were not installed (2005), or only operated for part of the season (2006 and 2008) the average female proportion of the other years between 1998 and 2011 (28%) was used (Fig. 5). Biological characteristics from harvested grilse in FSC fisheries on the SW Miramichi are generally incomplete and sex ratios of small salmon returning to that branch have been and continue to be based on external observations at the Millerton index trapnet. The proportion of female small salmon returning to the SW Miramichi River was considered to be 11% in 2011 (Fig. 5).

The interpretation of ages from 1,046 scale samples collected from large salmon during the 2011 spawning migration identified 2SW maiden salmon as being the dominant component (85%) followed by repeat spawners (12%), 1SW maiden (3%) and 3SW maiden fish (0%; 1 fish). The proportion of 2SW salmon in 2011 was considerably higher than in the past and as a consequence the proportion of repeat spawners decreased in 2011 relative to previous years

(Fig. 6). Fifteen different spawning histories were identified from the large salmon scales in 2011; the oldest salmon had a total sea age of seven years and had spawned consecutively in each of the previous six years. Small salmon were almost exclusively aged as 1SW; only 5 of the 2,031 scales were identified as repeat spawning 1SW salmon.

In 2011, the average fork length for small and large salmon was 56.4 cm and 78.2 cm respectively, and similar to previous years (Fig. 7).

Similar to previous assessments, the fecundity relationship for Miramichi salmon detailed in Randall (1989) was used to determine the number of eggs carried by large and small salmon to each of the main branches in 2011 (Fig. 8). Eggs carried by large salmon in 2011 were the highest of the time series and largely attributable to the high proportion of female salmon and the increased abundance of 2SW maiden salmon. The contribution of eggs from small salmon returning to the Northwest Miramichi River was higher in 2011; a consequence of their increased proportion in the run (Fig 8).

The run timing of Atlantic salmon to the Miramichi River has been previously characterized as bimodal, with the first mode occurring in the summer (prior to August 31) and the second in the fall (after August 31) (Saunders 1967). Early and late runs of salmon to the Miramichi were obvious from DFO index trapnet catches in the early and mid 1990s but appears to have changed over time to a dominant summer mode. These changes in run timing have been consistent for both large and small salmon and on both major branches of the Miramichi River (Figs. 9 and 10). The proportion of salmon captured at DFO index trapnets by August 31 has increased on the SW Miramichi River since 1994, attaining levels of 75-90% in recent years. A similar pattern was observed for salmon on the NW Miramichi River but the trend was less pronounced (Fig. 11).

The reduced late run of salmon to the Miramichi River is not believed to be related to fish abundance but rather to a shift in behavior where they enter the river during the summer and no longer stage in Miramichi Bay until autumn. Decreases in the late run component have generally corresponded with increases in the early run component (Figs. 9 and 10). Similarly, single-day peak catches at DFO index trapnets, particularly on the SW Miramichi River, have switched from occurring in the fall previously to occurring in July and at levels higher than those experienced in the 1990s (Fig. 12). Since 2008, there has been the perception of high salmon abundance in the river during the summer angling season but low abundance during the fall.

Reasons for the potential shift in run timing from late season to early season are lacking, but one hypothesis is the avoidance of predators in Miramichi Bay. It is unclear why a typically late-run salmon would enter the river early in the season to face unknown, potentially hot, freshwater conditions for the following three months when it could stay in Miramichi Bay until the fall when water conditions became optimal for moving into the river. It is possible that these fish have hedged their bets on survival in freshwater for the summer rather than in Miramichi Bay. Other potential evidence for seal predation on salmon in SFA 16 is described under the section on Threats below.

Protection Barriers and Crown Reserve Angling

The headwater protection barrier on the north branch of the Southwest Miramichi River near Juniper only operated during part of the salmon run in 2010 and 2011 and counts are not comparable to the rest of the time series. Protection barriers on the Dungarvon and NW Miramichi rivers operated from early June to October 20 in 2011 and there were no washout

periods. The large salmon count (n=327) through the Dungarvon barrier in 2011 was the highest of the time series (1984-2011) while the small salmon count (n=712) was the highest since 1992 and 62% above the previous 5-year mean (Table 7; Fig. 13). The large salmon (n=298) count through the protection barrier on the NW Miramichi River in 2011 was the highest since 1999 and 44% above the previous 5-year mean. The small salmon count (n=996) at the NW barrier in 2011 was among the highest values of the time series, and 56% above the previous 5-year mean (Table 7; Fig. 13).

Angling in the Crown reserve stretches was considered to be good in 2011 with over 1,500 small and 274 large salmon captured (Dubee et al. 2011). The catch of large salmon in 2011 was the highest of the time series (1973-2011). The small and large salmon catches in 2011 were 67% and 82% above their previous 5-year means (Table 8). Effort (rod days) has remained relatively constant through the time series (Fig. 14).

ATLANTIC SALMON ADULT REMOVALS IN SFA 16

HOME WATERS

Harvest levels of small salmon and catch and release statistics for large salmon in the recreational fishery of the Miramichi River have not been available since 1997. Similarly, harvest levels of small and large salmon are incomplete for aboriginal FSC gillnet fisheries but considered reliable from FSC trapnet fisheries. In the absence of fisheries' harvests statistics, assumptions about removals are required so an assessment of conservation attainment can be made. In recent assessments, the harvest of large salmon in aboriginal FSC fisheries of the Miramichi River has been assumed to be 600 fish which is about 90% of allocations in fishery agreements. It is also assumed that 30% of the large salmon return is angled in the recreational fishery and that 3% of those die as a consequence of being caught and released. Harvest of small salmon in the recreational fishery is assumed to be 25% of the small salmon return estimate while 1,500 fish or about 20% of the small salmon allocations are assumed to be removed from aboriginal FSC fisheries.

The local aboriginal FSC fishery exploits a mixed stock of SW and NW Miramichi origin salmon and their relative proportion in the harvest is unknown. In previous assessments, the majority of harvested fish in aboriginal FSC fisheries were allocated to the NW Miramichi and did not consider the important movement of salmon and grilse between the major branches (Table 4). For the period 1998 to 2011, the following method was used to estimate removals of large and small salmon in aboriginal FSC fisheries of the NW and SW Miramichi estuaries.

The information from the trapnets on the SW Miramichi operated by Eel Ground First Nation is considered reliable. There is virtually no harvest of large salmon from these trapnets and there are no gillnet fisheries on the SW Miramichi River for which harvest assumptions need to be made. The harvest of large salmon of SW Miramichi River origin was calculated based on the 2011 proportion of large salmon tagged at the Cassilis trapnet that were of SW Miramichi origin (37% in 2011) (Table 4). This proportion was applied to the assumed harvest of 600 large salmon in the Northwest Miramichi and considered to represent the harvest of large SW Miramichi salmon, 222 fish. The remainder of the assumed large salmon harvest was considered to have been of NW Miramichi origin fish, based on the proportion of large salmon tagged at the Cassilis trapnet that remained in the NW branch (63% in 2011; Table 4).

The same approach was used to divide the FSC harvests of small salmon into NW and SW Miramichi origin fish. Tagging information from Eel Ground trapnets on the SW Miramichi River

in 2011 indicated that 82% of small salmon remained in the SW branch while 18% moved to the Northwest branch (Table 4). These proportions were considered to represent the contributions of SW and NW Miramichi origin fish in Eel Ground's trapnet harvest of small salmon. The tagging information at Cassilis was used to derive the rate of exchange for small salmon from the Northwest branch to the Southwest branch. In 2011, 85% of the assumed 1,500 small salmon harvest in FSC fisheries on the Northwest Miramichi were considered to be NW Miramichi origin fish, while 15% were considered to be SW Miramichi origin fish.

There were no changes to the method of estimating removals of small or large salmon in the recreational fishery.

The harvest assumptions described above equate to the approximate loss of 760 large and 15,500 small salmon in 2010 and 900 large and 13,700 small salmon in 2011. The majority (85%) of small salmon losses occurred in the recreational fishery, while 90% of large salmon losses occurred in estuarine aboriginal FSC fisheries (Fig. 15).

The harvest of small salmon (all fisheries) generally accounts for the majority of the annual egg loss to the Miramichi River and its two branches (average of 60% for both the Miramichi and NW Miramichi, and 58% for the SW Miramichi between 1998-2011) (Fig. 16). In years of low small salmon returns, the proportion of eggs lost from the harvest of large salmon increases (2009 for example). The proportion of eggs lost in the returns of small salmon for the period 1998 to 2011 averaged 36% (30-60%) for the Miramichi River overall, 29% (27-34%) for the SW Miramichi River, and 44% (33-81%) for the Northwest Miramichi River (Fig. 17). Proportionally fewer eggs were lost in the returns of large salmon with average estimates between 1998 and 2011 at 4% (3-6%) for the Miramichi River, 2% (1-3%) for the SW Miramichi River, and 14% (6-27%) for the NW Miramichi River (Fig. 17).

HARVESTS ABROAD

West Greenland

Atlantic salmon of North American origin undergo long oceanic migrations and are harvested in a mixed-stock local consumption fishery at West Greenland. Tags applied to smolts and adult salmon in SFA 16 have been returned consistently from the West Greenland fishery and were again in 2011 (Table 9). The fishery at West Greenland has reported catches of 9 to 43 t in the past ten years, with the second highest catch since 1997 reported for the 2010 fishery at 40 t (plus an estimated 10 t of unreported catch). The estimated catch of North American origin salmon at West Greenland has annually varied between 2,300 and 10,000 fish, with 93% to 98% of the catch being 1SW non-maturing salmon; fish destined to have been 2SW or 3SW maiden salmon, had they not been captured. The monthly mortality rate of salmon from the time of the West Greenland fishery (August to December) to the return to home waters (July of the following year) has been estimated to be 0.03 per month, equal to a survival rate of 0.74 over the 10 month period.

From the run reconstruction conducted by the International Council for the Exploration of the Seas (ICES) Working Group on North Atlantic Salmon (ICES 2011), we can estimate the number of SFA 16 origin 2SW salmon likely to have been harvested at West Greenland at the 1SW non-maturing stage with the following approach and input data:

A) Total catch of salmon (in numbers) at West Greenland in year t

B) Catch of North American fish = Proportion of the catch which is North American origin x A (total catch)

C) Fish captured at West Greenland must be discounted for the proportion that would have died before returning to Canada. An instantaneous mortality rate of 0.03 per month was used. The fishery at West Greenland runs from mid-August to November. So time between fishery at West Greenland and returns to Gulf would be (September fishery in 2009 to returns to Gulf in July 2010) 10 months so mortality (proportion) would = 0.259 (1-exp(-0.03*10)).

Using estimates of returns of 2SW salmon in North America in year t+1, we can estimate the proportion of the catch of North American fish from the SFAs in Gulf Region, if it is assumed that the stocks from all regions of eastern North America are exploited at the same rate at West Greenland.

D) The harvest of SFA 16 origin salmon at West Greenland can be calculated as SFA 16 returns of 2SW / North America returns of 2SW x C.

E) The proportion of the 2SW returns from SFA 16 lost due to the fishery are: D / (D + SFA 16 returns of 2SW)

The estimated catch of 2SW equivalents of SFA 16 origin salmon at West Greenland in the past ten years has averaged 966 (range 592-1,297) fish annually (Table 10), representing 4% to 15% of the potential 2SW returns to SFA 16.

Labrador and St. Pierre Miquelon

Most of the high seas salmon losses since the closure of Canadian commercial fisheries in 1998 have occurred at West Greenland, although some of the losses may occur in the Labrador FSC and resident food fisheries or in the fishery at St. Pierre & Miquelon. The landings of large salmon from the Labrador fishery have varied between 6 and 17 t during 2001 to 2010 with 2SW salmon catches estimated to be in the range of 700 to 2,000 fish per year, the majority expected to be of Labrador origin. The fishery at St. Pierre & Miquelon has captured between 2 and 3.6 tons in the past ten years, about three quarters were small salmon, the remainder large salmon with estimated 2SW catches of just over 200 to just under 400 fish annually. The proportion of salmon harvests in this fishery that were destined for SFA 16 waters are unknown.

ESCAPEMENT RELATIVE TO CONSERVATION REQUIREMENT

The conservation requirement for rivers in SFA 16 is the egg deposition rate of 2.4 eggs per m^2 (CAFSAC 1991; Chaput et al. 2001). Egg requirements for 77% of the rivers in SFA 16 are less than 1.5 million eggs or roughly less than 250 large salmon (see Table 1 in Chaput et al. 2010). Based on average biological characteristics, the conservation requirements are about 16,000 and 7,300 large salmon for the Southwest and Northwest Miramichi rivers respectively.

Considering the biological characteristics of salmon observed in 2011, eggs carried by returning large and small salmon were sufficient to attain 192% of the conservation requirement for the Miramichi as a whole, 220% for the SW Miramichi River, and 132% for the NW Miramichi River (Figs. 18, 19, 20). Considering the assumed levels of exploitation on the resource, the salmon escapement to the river was sufficient to meet the conservation levels of 180% for the Miramichi as a whole, 212% for the SW Miramichi River, and 109% for the NW Miramichi River (Figs. 18, 19, 20).

The escapement of salmon to the Miramichi River as a whole was sufficient to meet the egg deposition requirements repeatedly between 1992 and 1996 but only three times (2001, 2004, and 2011) during the period 1997 to 2011. The conservation requirement was attained on the Southwest Miramichi River between 1992 and 1996, and intermittently (7 times and 3 marginal misses) between 1997 and 2011. The Northwest Miramichi achieved conservation levels between 1992 and 1997 but only twice (2001 and 2011) during the 1998 to 2011 period.

EXPECTATIONS FOR 2012

The abundance of small salmon returns to the Miramichi can generally infer the number of 2SW and total large salmon returns in the following year, but there have been exceptions. For example, the returns of large salmon in 2010 were better than expected based on the low returns of small salmon in 2009 (Chaput 2010). Since 1998, the ratio of large salmon returns to small salmon returns the previous year has averaged 0.68 (range 0.41-1.56) which is equivalent to one large salmon for every 1.6 small salmon the previous year (Fig. 21). Similarly, the average (1998-2011) ratio between small salmon returns in a year and 2SW maiden salmon returns in the following year is 0.41 (0.22-0.86), the equivalent of 2.7 grilse to one 2SW salmon the following year. It is likely that the large salmon return to the Miramichi in 2012 will be in the order of 20 to 30 thousand fish; levels that would be adequate to meet conservation requirements.

The relationship between smolt abundance in a given year and the return of 1SW or 2SW salmon in subsequent years is unclear but the number of smolts estimated to have left the Northwest Miramichi River in 2011 was the highest among the short time series of estimates (over 4.0 smolts per 100 m^2 see section below).

FRESH WATER PRODUCTION

JUVENILE ATLANTIC SALMON

Miramichi watershed electrofishing surveys

Backpack electrofishing surveys of the freshwater sections of the Miramichi watershed have been completed annually since 1970 (Moore and Chaput 2007). A combination of open (n = 46) and barriered (also referred to as closed n = 3) sites were sampled in 2011. As in previous assessments, abundance of fry and parr at closed sites was estimated by the depletion method described by Zippin (1956). The relationship between abundance estimates for fry and parr derived from the depletion method and those from the catch-per-unit-of-effort method during the initial sweep at closed sites provided the linear functions with which fry and parr abundance at open sites was estimated (Chaput et al. 2005). Calibration data collected between 2006 and 2011 (2008 omitted) were used to develop the linear function that predicted densities from CPUE information in 2011 (Fig. 22). The large confidence intervals around the intercept and the prediction of negative abundances when catches were 0 or low necessitated forcing the line through the origin.

Similar to the previous assessment, densities of fry, small, and large parr were summarized according to the four major tributaries of the Miramichi River that are under tidal influence (the SW Miramichi, Renous, NW Miramichi and Little Southwest Miramichi rivers) (Chaput et al. 2010). Average juvenile densities were included in the trend analysis only when four or more sites per large river system were surveyed in a given year (Table 11). Juvenile densities were

compared with average densities before and after the closure of the commercial fishery in 1984. Average densities before the closure of the fishery were calculated for the years 1970 to 1984 for fry, for 1970 to 1985 for small parr, and for 1970 to 1986 for large parr.

Salmon fry were captured at all but one of the 49 sites surveyed in 2011 indicating that adult salmon continue to spawn throughout the Miramichi watershed. The average abundance of fry in the SW and NW Miramichi rivers in 2011 was below the post-commercial fishery average but well above average densities estimated when the fishery was active prior to 1984. Levels of fry in the Renous and Little Southwest Miramichi rivers were similar to their 1985-2011 long term averages (Figs. 23 and 24). In 2011, average fry levels were similar in each of the four large rivers (range 44 per $100m^2$ on the LSW to 64 per $100m^2$ on SW).

Small parr abundance on the SW Miramichi River has been below the post commercial fishery average for the last 7 years but not at the lower levels observed when the fishery was occurring. Average small parr densities in the Renous, NW Miramichi, and LSW Miramichi rivers were at or near their respective 1986-2011 averages (Figs. 23 and 24). The lowest small parr abundance in 2011 was observed on the LSW Miramichi ($13/100m^2$) and SW Miramichi ($14/100m^2$) rivers, but they were twice as high on the Renous ($26/100m^2$) and NW Miramichi ($32/100m^2$) rivers. Average large parr densities in 2011 were near the post commercial fishery average for their respective rivers and ranged between $4/100m^2$ on the LSW Miramichi River to $7/100m^2$ on the NW Miramichi River (Figs. 23 and 24).

The total biomass of all juvenile salmon has remained unchanged and equivalent to the long term average between 1986 and 2011 for each of the four major rivers. Highest estimates of juvenile salmon biomass in 2011 were observed on the NW Miramichi River (450 $g/100\ m^2$), followed by the Renous River, ($386g/100m^2$), the SW Miramichi River ($355g/100m^2$) and the LSW Miramichi River ($250g/100m^2$) (Fig. 25).

Southeast New Brunswick electrofishing surveys

Electrofishing surveys in the Cocagne, Buctouche, Richibucto, Kouchibouguacis, and Kouchibouguac rivers of southeastern New Brunswick were infrequent between 1974 and 2004 but have been conducted annually since 2005. The electrofishing surveys of SE New Brunswick all consist of open sites and the same method of deriving abundance estimates is used as what was described above for the Miramichi watershed.

Fry abundance in all five rivers was similar in 2011 and ranged from a low of 18 per $100\ m^2$ in the Richibucto River to a high of 27 per $100m^2$ in the Kouchibouguac River. With the exception of the low fry density in the Kouchibouguac River, fry abundance in the other four rivers was near or above the average fry density for their respective rivers since the 1998 closure of all fisheries in SFA 16B (Figs. 26 and 27). Similar densities of parr (all ages combined) were estimated in the Cocagne (9 per $100m^2$), the Buctouche (8 per $100m^2$), and the Kouchibouguacis (5 per $100m^2$) rivers but significantly less than those estimated in the Kouchibouguac (18 per $100m^2$) and the Richibucto (20 per $100m^2$) rivers. With the exception of the high parr abundance in the Richibucto River, parr densities in the other four rivers were below the average parr level for their respective rivers since the 1998 closure of fisheries in SFA 16B (Figs. 26 and 27).

Salmon fry densities of 40 per $100\ m^2$ were observed in the Buctouche River in 2000 following an adult salmon assessment the previous year that determined that conservation had been met (Atkinson and Peters 2001). Similar levels of fry were observed in the Buctouche, Cocagne, and

Kouchibouguac rivers in 2005, suggesting that spawning requirements may have been achieved for those rivers in 2004. Densities of salmon fry in all southeastern New Brunswick rivers have been below 40 per 100m^2 since 2005; an indication that they have not likely met conservation requirements since that time.

ATLANTIC SALMON SMOLTS

Interest in understanding marine survival of Atlantic salmon has lead to annual smolt monitoring programs in tributaries and/or the main branches of the Miramichi River since 1998. Mark and recapture experiments have been the basis from which smolt abundance has been estimated. Typically, smolts were captured with a rotary screw trap (rst or smolt wheel) near the mouth of a tributary, tagged, transported back upstream several kilometers, and released to encounter the smolt wheel a second time. This method, often referred to as recycling, permitted smolt estimates for individual tributaries (Chaput et al. 2002). The simultaneous operation of an estuarial trapnet has functioned as a secondary recapture facility and has provided a means of estimating smolt abundance for either the Southwest or Northwest Miramichi rivers (Chaput et al. 2002). Estimates of smolts leaving the Northwest or Southwest Miramichi rivers are of interest since adult salmon returning to those branches are estimated annually and trends in marine survival can be evaluated. There are no smolt monitoring programs in other SFA 16 rivers.

Smolt production on the SW Miramichi River between 2001 and 2010 (missing 2005) averaged over 1 million smolts annually and corresponded to 2.9 smolts per 100m^2 (range 1.0 – 6.1) (Table 12). These estimates are higher than those derived for the NW Miramichi during the 1999-2006 and 2011 years although some of the estimates are considered unreliable due to incomplete sampling. Average smolt abundance for the years when a program was in place was over 300,000, the equivalent to an average production rate of 2.0 smolts per 100 m^2 (range 0.9 – 4.6). The Northwest estimate of 4.6 smolts per 100 m^2 in 2011 is the highest of the time series (Table 12). These estimates of smolt production are low relative to the 3 to 5 smolts per 100 m^2 considered to be suitable production rates for the Miramichi River (Elson 1975). Estimates of smolt production for the entire Miramichi River between 1953 and 1958 ranged from 0.8 to 2.6 million smolts which equates to a production rate of 1.5 to 4.8 smolts per 100 m^2 (Kerswill 1971).

Recent rates of return estimated for smolts to 1SW salmon to the Southwest Miramichi River have averaged 3.2% (1.0-8.6%) and to 2SW salmon, 1.5% (0.5-3.3%) (Table 12). Return rates for 1SW salmon to the Northwest Miramichi River averaged 3.6% (1.4-6.6%) and for 2SW salmon 0.7% (0.2-1.2%) (Table 12). The relationship between smolt abundance and their subsequent return as 1SW or 2SW salmon is weak and precludes predictions about returns of 1SW and 2SW salmon in subsequent years (Fig. 28). For example, return rates of small salmon in 2011 to the Southwest Miramichi River were relatively good but not the abundance that might have been expected from the 2010 estimate of smolt production for that river (6.2 per 100m^2).

THREATS

Multiple threats to Atlantic salmon have been documented in Cairns (2001) and those specific to SFA 16 (fisheries, environmental constraints, disease, land use, and invasive species) were covered in Chaput et al. (2010).

In July 2012 the New Brunswick Department of Natural Resources reduced the maximum width of buffer zones applied on Crown land to protect water quality and aquatic habitat from 60

meters down to 30 meters. Thirty meters is consistent with requirements under the NB Clean Water Act, its' regulations and implementation related to timber harvesting operations on private lands in the province. Though the maximum width has been reduced, now all watercourses on Crown land with continuous flow will receive 30 meter buffers regardless of stream width which is different than the previous requirement that only watercourses with a channel width of 0.5 meters and greater be afforded a 30 meter buffer zone. Sixty meter buffer zones will be applied on all lakes and rivers to protect their recreation and aesthetic value. Crown angling reserve and lease waters will get buffers 90 meters wide while Canadian Heritage Rivers receive buffers consistent with their management plans (S. Gordon, NB DNR, pers. comm.). The potential impacts of this change to salmon and their habitat are unclear.

Large and small salmon with significant wounds have been sampled at the DFO index trapnets on both the NW and SW Miramichi rivers since 2009. The wounds are specific to salmon and none of the other 10+ species captured at these facilities show any signs of trauma. General patterns of wounds have emerged and efforts to categorize them properly will occur in future field operations. Eight general wound categories were identified and can be described as wounds from fishing gear (net marks), wounds from sea lamprey, puncture wounds specific to the dorsal side, wounds specific to the caudal peduncle, severe mid-body wounds – gash, severe mid-body wounds – irregular pattern, lesser mid-body wound – scraping pattern, and wounds that are healing or healed.

Wounds from fishing gear (gillnets in particular) are easily recognizable and often appear as a ring around the fishes' head or mid-section, and is usually accompanied by severe scale loss at the site of the trauma. Other wounds from fishing gear include torn or frayed fins, general poor physical condition of the fish and scale loss; the likely consequence of manipulation in a fishery (gaspereau or mackerel). Lamprey wounds are perfectly circular and range in size depending on the size of the lamprey that was attached. These wounds can be found anywhere on the fish but are usually on the side. The occasional small lamprey is observed still attached to the fish but in most cases only the wound is observed. Puncture wounds presumed to be inflicted by diving birds are generally circular and always on the dorsal side of the fish, usually anterior to the dorsal fin and close to the head. The wounds specific to the caudal peduncle are generally deep lacerations which expose the fishes' flesh. The most troublesome of the wounds are the severe mid- body wounds (gash) which are long, deep lacerations that exposes the flesh or entrails of the fish. These wounds are usually on the ventral sides of the fish and the cause is unknown. The severe mid-body wounds with irregular patterns are usually found on the posterior portion of the fish on the sides or back. Seals are potentially the cause of these wounds. Lesser mid-body wounds with a scraping pattern are identified by three or four evenly spaced scrapes usually along the fishes' dorsal side. These scrapes displace scales but are rarely severe enough to cut the skin. Many of the wounds described above are also observed completely healed or in the process of healing.

In 2011, 5.0% of the large salmon catch and 2.2% of the small salmon catch at DFO's index trapnet at Millerton on the SW Miramichi River was identified as having net marks or a wound as described above (other than a lamprey or healed). Similar levels of wounded salmon (3.3% of large and 4.3% of small) were observed at the Cassilis trapnet on the NW Miramichi River. Overall, 4.3% of the large and 3.2% of the small salmon sampled at index trapnets were wounded in 2011. These percentages reflect only the number of fish that escaped the source of the wound and remained healthy enough to make it at least as far as the Miramichi trapnets. Net marks were observed on salmon in the NW Miramichi between June 15 and August 2 but 95% of observations occurred between June 21 and July 15 (Fig. 29). Net marks on salmon captured at Millerton were observed between June 8 and September 3 but 96% of observations

occurred between June 8 and July 22. Salmon with wounds (other than lamprey or healed) were observed at Cassilis between June 23 and August 1 with 92% of occurrences between June 23 and July 15. Wounded salmon were observed at Millerton between June 6 and September 6 with 97% of occurrences between June 6 and August 1 (Fig. 29).

The majority of net marks in 2011 were distinctive rings around the heads of small salmon. It is most likely that these fish were from entanglement in gillnets used in the Atlantic mackerel fishery off northern PEI (see section of fisheries' impacts on salmon discussed in detail below). We speculate that gannets may be the cause of the dorsal puncture wounds since these observations have been made recently (DFO C&P pers. comm.). Foraging seals or sharks could be the cause of the caudal peduncle and mid body wounds but we have no data nor observations to substantiate these hypotheses. Different stages of healing have been observed on the wounds which lends to the perception that some were inflicted very recently (days ago; still bleeding), weeks ago (new tissue over the wound no longer bleeding), and months ago (obvious old wound, completely healed, scales regenerated).

IMPACTS TO OTHER SPECIES AND HABITAT FROM SALMON FISHERIES

Regulations require anglers to use artificial flies when targeting Atlantic salmon in scheduled waters of SFA 16. Brook trout are susceptible to capture using this method and retention fisheries for this species are regulated by daily bag and size limits. Thousands of young salmonids are hooked and released on an annual basis while targeting adult salmon. The mortality associated with this activity is unknown but likely high and dependant on hook placement and care removing the hook. Other species such as American shad, white sucker, and striped bass, are occasionally hooked when targeting Atlantic salmon but the mortality on these species is believed to be minimal. There is some interest by user groups to change regulations so all hooks with a barb must be pinched in scheduled waters of SFA 16.

The majority of angling in SFA 16 occurs by wading. Wading may cause disruption to the substrate which impacts habitat but these are not well documented and have not been quantified. The invasive freshwater algae *Didymosphenia geminata* (didymo) may have a negative effect on salmonid habitat but its presence has not yet been confirmed in rivers of SFA 16. The proper disinfection of waders, boats and fishing gear after angling in didymo-infected waters (some rivers of SFA 15) are essential to limiting its spread to other watersheds.

Aboriginal FSC fisheries for Atlantic salmon mainly occur in the estuaries of SFA 16 and gillnets and trapnets are the most common gears employed. The run-timing of salmon in the spring and/or fall overlap with migrations of other species which are intercepted while targeting salmon. Unwanted bycatch from trapnets can be released alive while it is usually dead or harmed in gillnets. Striped bass, American shad, and brook trout are the most common species intercepted in FSC fisheries targeting Atlantic salmon but only bycatch mortality for striped bass has been evaluated for this fishery in the Gulf region. The Allowable Harm Assessment for southern Gulf striped bass indicated that the FSC aboriginal gillnet fishery can intercept several thousand striped bass with corresponding high mortality on individual fish. First Nation estimates of current annual striped bass losses in FSC fisheries for Atlantic salmon were greater than 2,000 fish (DFO 2011).

Both trapnets and gillnets disrupt the substrate of the estuaries but the impacts to salmon habitat from these activities is considered to be minimal.

IMPACTS TO SALMON AND HABITAT FROM OTHER FISHERIES

Several commercial fisheries occur in the estuaries and surrounding marine waters of SFA 16 and many have the potential of intercepting Atlantic salmon. Chiasson et al. (2002) surveyed DFO Conservation and Protection (C&P) officers with the objective of identifying the species and the level at which they are intercepted in the gaspereau, Rainbow smelt, American eel, and Atlantic silverside fisheries of the southern Gulf. Bycatch levels were ranked relatively as minimal (1), moderate (2), and large (3), and absolute numbers were not requested. Presumably, a rank of 0 indicated that no bycatch for that species was occurring in the jurisdiction that a detachment was responsible for.

Gaspereau are targeted with trapnets in many estuaries of SFA 16 during May and June. The gaspereau catch is loaded alive and the unwanted bycatch can be quickly returned to the water. C&P officers identified large quantities of salmon bycatch in the gaspereau fishery of the Miramichi and minimal levels in the Big Tracadie, Buctouche, Richibucto, and Kouchibouguacis rivers. These levels of bycatch are consistent with the run timing of salmon to each of these rivers (i.e. large quantities due to the early-run salmon to the Miramichi River when the fishery is occurring but minimal quantities in the other rivers which typically have late runs of salmon and only after the fishery is complete). All other locations where gaspereau is fished in SFA 16 were assessed by C&P as having no salmon bycatch (Chiasson et al. 2002).

Large and small salmon (black and bright) are regularly observed during the bycatch sampling for striped bass in the gaspereau fishery of the Northwest Miramichi and the catch can range from 0 to a maximum of 100 in a single 24 hr trapnet catch (S. Douglas, pers. comm.). Catches of salmon usually increase as the gaspereau season progresses and this is considered when determining the end date for the gaspereau season. There is some salmon mortality in this fishery but efforts are made to discard all bycatch as soon as it comes on board. The total mortality of salmon from this fishery in SFA 16 is unknown.

American eels are typically targeted with fyke nets in estuaries and shallow bays of SFA 16 during the spring or late summer-early fall. The eel catch is loaded alive and the unwanted bycatch can be quickly returned to the water. C&P officers ranked the abundance of salmon bycatch in eel fisheries as high in the Miramichi and Tabusintac rivers and minimal in the Richibucto River. Salmon bycatch in eel fisheries at all other locations in SFA 16 were assessed as non-existent (Chiasson et al. 2002). There are no estimates of mortality on salmon intercepted in the eel fisheries of SFA 16 but is considered to be relatively minor.

Rainbow smelt are typically targeted with box nets or gillnets in estuaries or bays of SFA 16 during the November to March period. C&P officers ranked the abundance of salmon bycatch in smelt fisheries as high in the Miramichi, Tabusintac, Big Tracadie, and Little Tracadie rivers and moderate in the Buctouche, Richibucto, Kouchibouguacis, and Kouchibouguac rivers. Salmon bycatch in smelt fisheries at all other locations in SFA 16 were assessed as non-existent (Chiasson et al. 2002). DFO Science has sampled the smelt fishery of the Miramichi River at Loggieville and Chatham on many occasions and occasionally in the Tabusintac River over many years with a single observation of one large salmon in this fishery in Miramichi and another in the Tabusintac River (S. Douglas and G. Chaput, pers. comm.).

There are no fisheries for Atlantic silversides in SFA 16.

Atlantic salmon are intercepted in the drift and surface gillnet bait fisheries for Atlantic mackerel and herring off the northern shore of Prince Edward Island every year (DFO C&P pers. comm.).

Drift gillnets cannot exceed 500 fathoms (0.91 km) in length and usually measure 2 to 2.5 m in depth. During the spring season (January 1 to June 30) minimum and maximum mesh size is 57.1 mm and 83 mm respectively. The fall season occurs between July 1 and December 1 with a minimum mesh size of 66.7 mm and maximum of 83 mm. The drift gillnet fishery occurs in May and June and approximately 50 vessels from the provinces of PEI, NB, and NS form the fleet. Gillnets are typically drifted 12 to 50 miles from shore. Surface gillnets are smaller and measure 60ft in length and 10 ft in depth. Surface nets are used from July to September and are generally anchored 2 to 3 miles from shore.

Inspections of eight drift net vessels by C&P staff on June 11, 2011 resulted in three violations of possession of Atlantic salmon (n = 4 fish). Each of the fishers was convicted and paid fines ranging between $700.00 and $900.00. Sources informed C&P that small and large salmon were captured every night of the fishery and that overnight drifts during a 3-week period at the end of May and early June 2011, resulted in salmon catches ranging between 5 and 30 per night. Some salmon were released unharmed, while the majority were dead, not in very good condition, or being eaten off of the net by seals. There have also been observations of gannets diving for entangled salmon during the retrieval of gillnets during this fishery (DFO C&P pers. comm.).

Several observations of small salmon with net marks around their head were made between May and June at DFO index trapnets on both the SW and NW Miramichi rivers in 2011. It is hypothesized that these fish became entangled in gillnets used for mackerel but escaped the fishery to continue their spawning migration for the following reasons. First, the mesh size of the mackerel gillnets would be of an appropriate size to gill or almost gill small salmon. Gillnets in the aboriginal fisheries of the Miramichi are generally constructed of 5 inch mesh and only effective at capturing small salmon around the midsection. Secondly, the timing of the observations at DFO index trapnets was consistent with the timing of the mackerel fishery in May and June and there were no more observations of small salmon with net marks around their head after mid July in 2011 (Fig. 29).

There is no indication that any of these fisheries pose a threat to Atlantic salmon habitat.

FRAMEWORK OF INDICATORS

Assessments of Atlantic salmon are anticipated to be conducted on a multiyear cycle. This has raised the question of how to inform on the status of salmon populations in the non-assessment year. The terms of reference for this Regional Advisory Process specifically asked for an indicator or a framework of indicators that could be used to infer the status of salmon in the non-assessment year.

The bulk of the salmon information in SFA 16 comes from the Miramichi River and was therefore the focus for this exercise. A cursory examination of the linear relationships between small and large catches at DFO index trapnets (until the end of August and the end of the season), barrier counts, crown reserve catches and return estimates of small and large salmon to the branches and overall for the Miramichi were conducted for the years 1998 to 2011 (Table 13). Indicators using the juvenile salmon information from the Miramichi River were not explored.

The linear relationships between barrier counts or crown reserve angling catches and return estimates were weak and uninformative (Table 13). Small salmon catches at individual or combined index trapnets and the return estimate of small salmon to the branches or overall to

the Miramichi had the strongest correlation. Correlations for small salmon catches at trapnets at the end of August or at the end of the season and return estimates of small salmon were similar. Catches of large salmon at trapnets were not a good indicator of annual returns in any of the scenarios (Table 13).

Information on adult salmon returns to the Miramichi River has been prepared annually since the early 1980s but formal assessments have been less regular. Managers and NGOs expect estimates of adult returns on a yearly basis and these have been provided, even without peer review. The annual estimates of salmon returning to the Miramichi River have broader implications than the local management of the resource. The run of Atlantic salmon to the Miramichi River is the largest in Canada and makes the largest contribution to North American salmon which the ICES assesses on an annual basis. The estimate of salmon returns to the Miramichi River is itself, part of a framework of indicators that ICES uses to inform on the status of North American salmon in the intervening years of the multi-year advice cycle. For these reasons, estimating the abundance of adult salmon returning to the Miramichi River will continue on an annual basis.

UNCERTAINTIES AND KNOWLEDGE GAPS

There is no mechanism to reliably evaluate removals of small or large salmon from the aboriginal or recreational fishery so assumptions about harvest levels and catch and release mortality are required to assess spawning escapements. Depending on the accuracy of the assumed levels of removals, the level of conservation attainment may be under or over estimated. The lack of catch statistics precludes any evaluation of current or potentially new management measures.

The confidence surrounding estimates derived from any mark recapture model increases with the number of recaptures. The number of tags applied to small and large salmon and the number of recaptured fish in 2011 was neither the highest nor the lowest of the time series. The hierarchical Bayesian framework is informative during years of poor mark recapture data (Chaput and Douglas 2012).

The movement of small and large salmon between the Northwest and Southwest Miramichi estuaries decreases the confidence in the estimate of run sizes to the individual branches.

The hierarchical Bayesian model used to derive estimates of run size makes several assumptions that have not been validated. The potential differences in tagging and handling mortality over the season and at varying water temperatures should be explored. Similarly the catch efficiency of trapnets and exchange rates of large and small salmon between the branches may vary over the course of the season.

The abundance of early run salmon to the Miramichi River has progressively increased in the last decade while the late run component has decreased. The change in run-timing appears to be a behavioural response to some unknown cause and not related to a reduced abundance of fall run fish.

The increased observations of large and small salmon with wounds at index trapnets in the Miramichi River was a concern in 2011. Wounds ranged in severity from minor scratches to deep lacerations and the cause remains unknown. The increase in significant wounds suggests increased mortality on the stock but the total effect remains unclear.

While electrofishing surveys provide an indication of the previous year's spawning escapement, the level at which conservation was attained is difficult to validate with these data alone. Trends in juvenile abundance in individual rivers are considered to be relevant when an adequate number of sites and different habitats have been sampled.

Atlantic salmon are known to inhabit 39 rivers in SFA 16. The majority are small rivers which have no monitoring programs in place to sample adult or juvenile salmon. The lack of information makes it difficult to explore management options for these smaller rivers.

CONCLUSIONS

Median return estimates of large and small Atlantic salmon to the Miramichi River in 2011 were 34,090 (5^{th} and 95^{th} percentile: 23,010-63,610) and 45,880 (5^{th} and 95^{th} percentile:35,750-59,390), respectively. The large salmon return in 2011 was among the highest return estimates since 1970. Small salmon returns in 2011 were lower than in 2010 but equivalent to the highest estimates since 1994.

Returns of large and small salmon to the Southwest Miramichi River were 27,870 (5^{th} and 95^{th} percentile:17,140-58,150) and 31,710 (5^{th} and 95^{th} percentile:22,360-45,890), respectively and enough to exceed the egg conservation requirement (220%) before fisheries. After accounting for removals, the conservation level for the SW Miramichi River was still achieved (212%).

Returns of large and small salmon to the Northwest Miramichi were 5,147 (5^{th} and 95^{th} percentile:3,180-8,813) and 13,550 (5^{th} and 95^{th} percentile:9,976-18,680), respectively and adequate to exceed the egg conservation requirement before fisheries (132%) and after accounting for removals (109%).

Catches and counts of large and small salmon at provincial barriers and crown reserve angling stretches in 2011 were the highest or among the highest of the 28 year time series (1984-2011) and well above previous 5-year means.

The bimodal run timing of salmon to the Miramichi River (early and late runs) appears to have changed recently to a single dominant mode in the summer. The proportion of salmon captures at DFO index trapnets by August 31 has increased since 1994, attaining levels of 75-90% in recent years. The strength of the summer salmon run can inflate the perception of total abundance by user groups.

The strong return of 1SW salmon in 2011 suggests the potential for a strong return of 2SW salmon in 2012, possibly in the in the order of 20 to 30 thousand fish. The strong 2SW component in 2011 followed the strong return of 1SW fish in 2010 which was also consistent across most of the species range (ICES 2011).

Salmon continue to spawn throughout the Miramichi watershed. Juvenile abundance has remained relatively consistent at higher levels since the 1984 closure of the commercial fishery and the mandatory release of large salmon in the recreational fishery.

Salmon continue to spawn in rivers of southeastern New Brunswick but juvenile densities remain below levels that were observed in years when conservation was determined to have been met. It is inappropriate to compare juvenile salmon abundance directly among rivers when differences in habitat and carrying capacity have not been evaluated.

Atlantic salmon smolts continue to be produced annually and at a level that does not appear to be constraining adult abundance. Return rates of 1SW and 2SW salmon from smolt cohorts are highly variable and unpredictable. Marine survival remains the limiting factor to higher adult abundance.

At this time, a rigorous and informative indicator of adult salmon returns to SFA 16 has not been developed for non-assessment years. We suggest that the interest of user groups is important enough to warrant an evaluation of adult returns annually. Furthermore, the adult return estimates for the Miramichi are annual inputs into a larger framework of indicators for salmon returns to North America in years when ICES does not provide catch advice (ICES 2011).

ACKOWLEDGEMENTS

We thank Debbie Norton of the Northumberland Salmon Protection Association and Mark Hambrook of the Miramichi Salmon Association for their support and significant staff contributions to DFO assessment programs in the Miramichi River. Eel Ground and Metepenagiag First Nations continue to assist in the mark and recapture program for adult salmon in the Miramichi River. Staff of the NB DNR graciously provided the salmon catch and count information from their crown reserve angling and protection barrier programs. We are grateful for data and program updates provided by Esgenoôpetitj, Elsipogtog, and Buctouche First Nations and Les Amies de la Kouchibouguacis. We thank DFO Science staff Noella McDonald for the ageing of all salmon scales, Marie Clement, Peter Hardie, Maria Thistle, and Karen Robertson for conducting the southeast New Brunswick electrofishing program and providing updates of juvenile salmon densities for those rivers. Anita Doucette of Les Amies de la Kouchibouguacis, and Kouchibouguac National Park volunteer Kirk Roach provided assistance with the SENB electrofishing program.

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TABLES

Table 1. Allocations and removals of large and small Atlantic salmon according to license regulations and agreements in SFA 16 in 2011. Nrg refers to Native recreational gear, na not available.

				Allocation		Small salmon			Large salmon		
User group	Location	Gear	Qty	Small	Large	Released	Harrvested	Mortality	Released	Harrvested	Mortality
DFO Science	SW Miramichi Millerton	trapnet	1	0	0	2,073	0	13	742	0	19
DFO Science	NWMiramichi Cassilis	trapnet	1	0	0	1,201	0	12	483	0	7
Recreational anglers	Crown open waters of SFA 15 and SFA 16	angling	na	* < 157,002	0	na	na	na	na	na	na
Buctouche FN	Crown open waters of Miramichi	angling	na	110	0	na	na	na	na	na	na
Esgenoôpetitj FN	Tabusintac River	angling	na	**100	**100	na	na	na	na	na	na
Esgenoôpetitj FN	Tabusintac River	gillnet	na			na	na	na	na	na	na
Esgenoôpetitj FN	Tabusintac River	trapnet	2	112	304	x	x	x	x	x	x
Esgenoôpetitj FN	Tabusintac River	gillnet	13			na	na	na	na	na	na
Esgenoôpetitj FN	Miramichi Bay	gillnet	25	2,000	200	na	na	na	na	na	na
Esgenoôpetitj FN	Crown open waters of Miramichi and Bartibog	Nrg				na	na	na	na	na	na
Eel Ground FN	NW Miramichi	trapnet	1	2,660	185	na	na	na	na	na	na
Eel Ground FN	NW Miramichi	gillnet	11			na	na	na	na	na	na
Eel Ground FN	Crown open waters of Miramichi and Bartibog	Nrg	na			na	na	na	na	na	na
Eel Ground FN	NW Miramichi	fence	1	240	5	na	na	na	na	na	na
Eel Ground FN	SW Miramichi	trapnet	2	2,100	10	x	x	x	x	x	x
Eel Ground FN	SW Miramichi	gillnet	1			na	na	na	na	na	na
Eel Ground FN	Crown open waters of Miramichi and Bartibog	Nrg	na			na	na	na	na	na	na
Elsipogtog FN	Crown open waters of Miramichi	angling	na	200	0	na	na	na	na	na	na
Metepenagiag FN	NW Miramichi system	trapnet	3	4,000	500	x	x	x	x	x	x
Metepenagiag FN	NW Miramichi system	gillnet	12			na	na		na	na	na
Metepenagiag FN	Crown open waters of Miramichi	Nrg	na			na	na	na	na	na	na
NBAPC	Crown open waters of Miramichi	angling	na	260	0	na	na	na	na	na	na
NBAPC	Crown open waters of Tabusintac	angling	na	30	0	na	na	na	na	na	na
Illegal	Estimate of unreported catches	na	na	0	0	na	na	na	na	na	na
SFA 16 total				**< 168,834**	**1,304**	**3,274**	**0**	**25**	**1,225**	**0**	**26**

* Total tags issued with angling license sales to residents and non-residents of New Brunswick in 2011, not all effort occurs in SFA 16
** Kelt

Table 2. History of monitoring programs for large salmon and small salmon from smaller rivers of SFA 16 other than the Miramichi.

River	Year	Program date		Traps	Salmon catch		% Conservation	Source
		Start	End		Small	Large		
Tabusintac	1993	31-Jul	28-Oct	2	156	180	184%	Atkinson and Claytor 1994a
Tabusintac	1994	22-Aug	9-Nov	2	127	196	345%	Atkinson and Hooper 1995
Tabusintac	1996	27-Sep	2-Nov	2	292	284	245%	Douglas et al. 1999
Tabusintac	1998	22-Sep	31-Oct	2	111	77	364%	Douglas et al. 1999
Tabusintac	1999	26-Aug	31-Oct	2	179	198	250%	Douglas and Swasson 2000
Tabusintac	2002	19-Sep	8-Nov	2	73	40	na	Esgenoôpetitj FN
Tabusintac	2003	22-Jul	26-Oct	2	32	37	na	Esgenoôpetitj FN
Tabusintac	2004	21-Jul	26-Sep	2	46	8	na	Esgenoôpetitj FN
Tabusintac	2005	4-Aug	11-Oct	2	23	25	na	Esgenoôpetitj FN
Tabusintac	2006	11-Aug	29-Sep	2	8	1	na	Esgenoôpetitj FN
Tabusintac	2007	23-Aug	27-Oct	2	28	25	na	Esgenoôpetitj FN
Tabusintac	2008	17-Aug	13-Oct	2	21	18	na	Esgenoôpetitj FN
Tabusintac	2009	8-Aug	4-Oct	2	1	7	na	Esgenoôpetitj FN
Tabusintac	2010	17-Aug	25-Oct	2	39	15	na	Esgenoôpetitj FN
Tabusintac	2011	13-Aug	22-Oct	2	9	29	na	Esgenoôpetitj FN
Buctouche	1992	7-Oct	3-Nov	1	25	80	na	Atkinson 1993
Buctouche	1993	24-Jul	4-Nov	2	27	32	35%	Atkinson and Claytor 1994b
Buctouche	1994	28-Sep	4-Nov	2	15	43	72%	Atkinson et al. 1995a
Buctouche	1995	18-Sep	29-Oct	2	52	46	58%	Atkinson and Chaput 1996
Buctouche	1996	27-Sep	28-Oct	1	25	26	46%	Atkinson et al. 1997
Buctouche	1997	9-Sep	27-Oct	2	36	53	70%	Atkinson et al. 1998
Buctouche	1998	10-Sep	5-Nov	2	8	18	33%	Atkinson et al. 1999
Buctouche	1999	1-Sep	16-Oct	1	29	40	102%	Atkinson et al. 2000
Buctouche	2000	16-Sep	3-Nov	1	10	16	36%	Atkinson and Peters 2001
Buctouche	2006	27-Sep	19-Oct	1	12	35	na	Buctouche First Nation
Buctouche	2008	na	na	na	≥ 3	≥ 8	na	Buctouche First Nation
Buctouche	2009	na	na	na	≥ 5	≥ 28	na	Buctouche First Nation
Buctouche	2010	na	na	na	≥ 0	≥ 2	na	Buctouche First Nation
Buctouche	2011	na	na	1	≥ 21	≥ 43	na	Buctouche First Nation
Richibucto	1992	3-Sep	8-Nov	1	15	45	83%	Atkinson and Claytor 1994c
Richibucto	1993	11-Aug	2-Nov	2	13	11	na	Atkinson and Claytor 1994c
Richibucto	1994	8-Oct	6-Nov	1		1	na	Atkinson et al. 1995b
Richibucto	1997	30-Sep	5-Nov	1	24	21	15%	Atkinson and Cormier 1998
Richibucto	2004	7-Oct	11-Nov	1	15	27	na	Tremblay et al. in prep
Richibucto	2005	10-Aug	18-Nov	2	27	46	na	Elsipogtog FN/Parks Canada
Richibucto	2006	21-Sep	22-Nov	2	58	41	na	Elsipogtog FN/Parks Canada
Richibucto	2009	23-Aug	1-Nov	2	2	3	na	Elsipogtog FN/Parks Canada
Richibucto	2010	30-Aug	1-Nov	2	20	7	na	Elsipogtog FN/Parks Canada
Richibucto	2011	23-Sep	10-Nov	2	10	13	na	Elsipogtog FN/Parks Canada
Kouchibouguacis	2005	24-Sep	8-Nov	2	7	7	na	Friends of the Kouchibouguacis
Kouchibouguacis	2006	29-Aug	30-Oct	2	2	2	na	Friends of the Kouchibouguacis
Kouchibouguacis	2007	10-Sep	26-Oct	2	8	6	na	Friends of the Kouchibouguacis
Kouchibouguacis	2008	12-Sep	4-Nov	2	5	7	na	Friends of the Kouchibouguacis
Kouchibouguacis	2009	21-Sep	28-Oct	2	3	6	na	Friends of the Kouchibouguacis
Kouchibouguacis	2010	25-Sep	29-Oct	2	6	3	na	Friends of the Kouchibouguacis
Kouchibouguacis	2011	13-Sep	19-Oct	2	9	11	na	Friends of the Kouchibouguacis

Table 3. Small and large salmon return estimates to the Miramichi River (upper), the Southwest Miramichi River (middle), and Northwest Miramichi River (lower) (Chaput and Douglas 2012).

Miramichi River						
	Small salmon			Large salmon		
Year	median	2.5th	97.5th	median	2.5th	97.5th
1998	23,680	19,540	28,990	17,060	12,790	23,480
1999	22,430	19,500	26,420	15,750	12,210	20,230
2000	33,480	29,200	39,120	17,410	13,710	22,330
2001	27,470	23,520	32,250	22,700	19,590	26,270
2002	41,790	36,300	49,180	12,090	9,308	16,050
2003	28,260	23,680	34,450	20,210	16,270	26,120
2004	45,480	37,750	55,210	21,370	16,720	30,350
2005	30,550	23,980	39,560	18,860	14,410	26,460
2006	32,190	25,260	41,840	21,430	16,420	29,850
2007	26,000	20,050	35,480	17,890	14,010	23,940
2008	28,760	22,030	39,230	13,290	8,666	18,980
2009	11,520	8,374	17,060	19,070	15,360	25,500
2010	52,730	43,550	65,950	17,970	14,200	23,180
2011	45,880	35,750	59,390	34,090	23,010	63,610

Southwest Miramichi River						
	Small salmon			Large salmon		
Year	median	2.5th	97.5th	median	2.5th	97.5th
1998	15,260	11,590	20,410	13,370	9,519	19,800
1999	12,890	10,160	16,860	11,680	8,249	16,190
2000	20,730	16,540	26,500	12,610	8,926	17,550
2001	18,700	14,920	23,480	14,220	11,120	17,910
2002	26,370	21,150	33,120	10,260	7,486	14,300
2003	21,670	17,230	27,890	17,250	13,300	23,240
2004	32,910	25,300	42,820	17,790	13,090	26,930
2005	20,630	14,970	27,710	14,570	10,600	22,120
2006	26,100	19,500	35,870	17,270	12,750	25,760
2007	19,720	13,820	29,160	14,470	10,560	20,560
2008	21,740	15,400	32,200	11,580	6,998	17,350
2009	8,712	5,837	14,470	16,530	12,850	23,020
2010	34,010	25,300	47,500	13,850	10,210	19,230
2011	31,710	22,360	45,890	27,870	17,140	58,150

Northwest Miramichi River						
	Small salmon			Large salmon		
Year	median	2.5th	97.5th	median	2.5th	97.5th
1998	7,605	5,834	10,430	3,070	1,760	5,935
1999	8,613	7,164	10,530	3,584	2,470	5,214
2000	11,530	9,734	13,550	4,259	2,774	6,482
2001	7,925	6,361	9,922	7,297	5,135	10,180
2002	14,500	11,590	18,110	1,503	969	2,347
2003	5,844	4,456	7,874	2,403	1,573	3,648
2004	11,720	9,590	14,430	3,092	2,095	4,523
2005	9,425	6,441	14,970	3,732	2,180	6,698
2006	5,474	3,885	7,802	3,472	1,959	7,055
2007	6,029	4,645	7,699	2,941	1,818	4,629
2008	6,626	4,856	9,685	1,401	780	2,855
2009	2,602	1,834	3,949	1,998	1,231	3,230
2010	17,830	14,020	22,300	3,444	2,345	5,073
2011	13,550	9,976	18,680	5,147	3,180	8,813

Table 4. Rates of exchange between the two major branches of the Miramichi river for small and large salmon tagged on the Southwest or Northwest Miramichi rivers, 1998 to 2011 (Chaput and Douglas 2012).

Cassilis tags staying in Northwest Miramichi						
	Small salmon			Large salmon		
Year	median	2.5th	97.5th	median	2.5th	97.5th
1998	0.84	0.74	0.90	0.67	0.44	0.87
1999	0.85	0.77	0.92	0.69	0.50	0.89
2000	0.83	0.75	0.89	0.62	0.39	0.82
2001	0.80	0.70	0.87	0.58	0.42	0.71
2002	0.82	0.73	0.88	0.76	0.55	0.96
2003	0.86	0.78	0.93	0.66	0.49	0.80
2004	0.85	0.77	0.90	0.72	0.53	0.88
2005	0.84	0.76	0.91	0.76	0.54	0.93
2006	0.85	0.77	0.91	0.64	0.39	0.83
2007	0.88	0.81	0.95	0.54	0.34	0.71
2008	0.85	0.77	0.92	0.60	0.31	0.80
2009	0.88	0.80	0.97	0.75	0.52	0.96
2010	0.81	0.72	0.87	0.62	0.45	0.75
2011	0.85	0.75	0.92	0.63	0.38	0.83
Mean	0.84	0.71	0.94	0.66	0.35	0.91

Millerton tags staying in Southwest Miramichi						
	Small salmon			Large salmon		
Year	median	2.5th	97.5th	median	2.5th	97.5th
1998	0.93	0.88	0.96	0.95	0.87	0.99
1999	0.96	0.92	0.98	0.97	0.92	0.99
2000	0.96	0.93	0.98	0.95	0.89	0.98
2001	0.93	0.89	0.96	0.93	0.89	0.96
2002	0.90	0.86	0.94	0.92	0.85	0.96
2003	0.90	0.85	0.94	0.93	0.87	0.96
2004	0.94	0.90	0.96	0.94	0.89	0.97
2005	0.93	0.88	0.96	0.91	0.81	0.96
2006	0.90	0.83	0.93	0.91	0.80	0.96
2007	0.94	0.90	0.97	0.96	0.91	0.99
2008	0.96	0.91	0.98	0.95	0.87	0.99
2009	0.96	0.91	0.99	0.95	0.89	0.98
2010	0.94	0.91	0.97	0.97	0.93	0.99
2011	0.95	0.91	0.98	0.93	0.85	0.96
Mean	0.94	0.84	0.98	0.94	0.82	0.99

SW Enclosure tags staying in Southwest Miramichi						
	Small salmon			Large salmon		
Year	median	2.5th	97.5th	median	2.5th	97.5th
1998	0.84	0.77	0.91	0.89	0.76	0.97
1999	0.83	0.76	0.88	0.84	0.73	0.91
2000	0.82	0.76	0.86	0.82	0.69	0.90
2001	0.83	0.76	0.88	0.82	0.72	0.89
2002	0.81	0.72	0.86	0.92	0.83	0.98
2003	0.86	0.79	0.93	0.94	0.85	0.98
2004	0.81	0.72	0.87	0.86	0.74	0.93
2005	0.84	0.76	0.93	0.86	0.71	0.94
2006	0.83	0.74	0.91	0.85	0.66	0.94
2007	0.84	0.76	0.93	0.86	0.71	0.94
2008	0.84	0.75	0.94	0.91	0.76	0.99
2009	0.83	0.72	0.91	0.88	0.77	0.94
2010	0.84	0.77	0.90	0.91	0.83	0.96
2011	0.82	0.70	0.89	0.93	0.83	0.98
Mean	0.83	0.71	0.92	0.88	0.67	0.98

Table 5. Recapture scenarios (44) observed and their frequency for small and large salmon tagged in 2011. Recaptures in bold were used in the hierarchical Bayesian framework to estimate abundance in 2011 (Chaput and Douglas 2012). Numbers preceeded by an '' indicate fish that were recaptured twice in the same net and count both times as a recapture. Ang = angling, EG =Eel Ground, RB= Red Bank.*

Location				Salmon	
Tagging	**Recap 1**	**Recap 2**	**Recap 3**	**Small**	**Large**
NW Cassilis	NW Cassilis	NW Cassilis	NW Cassilis	1	
NW Cassilis	NW Cassilis	NW Cassilis		4	
NW Cassilis	NW Cassilis			19	14
NW Cassilis	LSW Ang			11	3
NW Cassilis	NW Ang			7	1
NW Cassilis	SW Ang				1
NW Cassilis	SW EG Lower			1	
NW Cassilis	SW EG Upper			1	3
NW Cassilis	Juniper Barrier				1
NW Cassilis	**LSW RB**			**11**	**8**
NW Cassilis	**NW Cassilis**	**LSW RB**		**1**	**1**
NW Cassilis	**SW Millerton**			**5**	**2**
NW Cassilis	**SW EG Upper**	**SW Millerton**			**1**
NW Cassilis	**SW Millerton**	**SW Ang**		**1**	
SW EG Lower	SW EG Lower			1	
SW EG Lower	SW EG Upper			2	2
SW EG Lower	SW Ang			2	1
SW EG Lower	Juniper Barrier				1
SW EG Lower	LSW Ang			1	
SW EG Lower	**SW Millerton**			**1**	**4**
SW EG Lower	**NW Cassilis**				**1**
SW EG Upper	SW EG Upper			4	4
SW EG Upper	SW EG Upper	SW Ang		1	
SW EG Upper	Renous Ang			1	
SW EG Upper	SW Ang			4	2
SW EG Upper	SW EG Lower			1	
SW EG Upper	**SW Millerton**			**7**	**3**
SW EG Upper	**SW Millerton**	**SW Millerton**		***1**	
SW EG Upper	**NW Cassilis**			**2**	
SW EG Upper	**NW Cassilis**	**NW Cassilis**		***1**	
SW EG Upper	**LSW RB**			**2**	**1**
SW Millerton	SW Millerton	SW Millerton		4	
SW Millerton	SW Millerton			55	13
SW Millerton	SW EG Upper			5	1
SW Millerton	Juniper Barrier			1	1
SW Millerton	Dungarvon Barrier			1	
SW Millerton	SW Ang			24	10
SW Millerton	Renous Ang			8	1
SW Millerton	Bartibog Ang				1
SW Millerton	NW Ang			1	
SW Millerton	**NW Cassilis**	**NW Cassilis**			***2**
SW Millerton	**NW Cassilis**			**3**	**3**
SW Millerton	**SW Millerton**	**LSW RB**		**1**	
SW Millerton	**LSW RB**			**1**	

Table 6. Tags retuned by anglers in the 2011 kelt and bright salmon fishery of the Miramichi River. Tag returns were summarized by season, size, recapture and tagging location. Tag returns from the kelt fishery are from the 2010 assessment program whereas tag returns from the bright fishery are from the 2011 assessment program.

				Initially tagged		
Season	**Size**	**No. tag returns**	**Recapture location**	**NW Cassilis**	**SW Millerton**	**SW Eel Ground**
Kelt	small	5	Northwest	4	1	0
Kelt	large	3	Northwest	2	0	1
Kelt	small	15	Southwest	9	3	3
Kelt	large	9	Southwest	5	2	2
Bright	small	20	Northwest	18	1	1
Bright	large	4	Northwest	4	0	0
Bright	small	44	Southwest	1	35	8
Bright	large	17	Southwest	1	13	3

*Table 7. Counts of large and small Atlantic salmon at the headwater protection barrier on the Northwest Miramichi River, the Dungarvon River, and the North Branch of the Southwest Miramichi River near Juniper for 1984 to 2011. Numbers preceded by an * represent information that was collected when the barrier facility was only partially operating.*

	Large salmon			Small salmon		
Year	Dungarvon	Northwest	Juniper	Dungarvon	Northwest	Juniper
1984	93		297	315		230
1985	162		604	536		492
1986	174		1138	501		2072
1987	202		1266	744		1175
1988	277	234	929	851	1614	1092
1989	315	287	731	579	966	969
1990	318	331	994	562	1318	1646
1991	204	224	476	296	765	495
1992	232	219	1047	825	1165	1383
1993	223	216	1145	659	1034	1349
1994	155	228	905	358	673	1195
1995	95	252	1019	329	548	811
1996	184	218	819	590	602	1388
1997	115	152	519	391	501	566
1998	163	289	698	592	1038	981
1999	185	387	698	378	708	566
2000	130	217	725	372	456	1202
2001	111	202	904	295	344	729
2002	107	121	546	287	595	1371
2003	158	186	920	389	478	912
2004	185	167	764	559	723	1368
2005	300	262	673	441	735	853
2006	217	214	*829*	468	469	*860*
2007	88	166	783	195	460	945
2008	131	164	692	673	1094	1083
2009	234	206	770	207	315	245
2010	228	284	*563	660	852	*307
2011	327	298	*381	712	996	*268
Overall average (84-10)	185	227	795	483	759	974
2011 relative to overall average	77%	31%	-52%	47%	31%	-72%
Previous 5 yr. average (06-10)	180	207	727	441	638	688
2011 relative to previous 5 yr. average	82%	44%	-48%	62%	56%	-61%

Table 8. Effort and angling catches of large and small Atlantic salmon from the Regular Crown Reserve waters of the Northwest Miramichi system, 1973 – 2011 (Dubee et al. 2011).

			Small		Large		Combined	
	Year	Effort	Catch	CPUE	Catch	CPUE	Catch	CPUE
	1973	2,648	1,210	0.46	138	0.05	1,348	0.51
	1974	2,940	1,259	0.43	121	0.04	1,380	0.47
	1975	2,694	1,391	0.52	125	0.05	1,516	0.56
	1976	2,791	1,280	0.46	157	0.06	1,437	0.51
	1977	2,119	1,120	0.53	266	0.13	1,386	0.65
	1978	2,557	594	0.23	170	0.07	764	0.30
	1979	2,448	1,150	0.47	79	0.03	1,229	0.50
	1980	2,835	1,306	0.46	159	0.06	1,465	0.52
	1981	2,886	1,953	0.68	89	0.03	2,042	0.71
	1982	2,203	1,816	0.82	134	0.06	1,950	0.89
	1983	2,269	823	0.36	167	0.07	990	0.44
	1984	2,179	1,240	0.57	229	0.11	1,469	0.67
	1985	2,269	1,563	0.69	206	0.09	1,769	0.78
	1986	2,456	1,676	0.68	156	0.06	1,832	0.75
	1987	1,839	1,072	0.58	88	0.05	1,160	0.63
	1988	2,432	1,860	0.76	102	0.04	1,962	0.81
	1989	2,535	1,595	0.63	127	0.05	1,722	0.68
	1990	2,502	1,587	0.63	144	0.06	1,731	0.69
	1991	2,395	612	0.26	77	0.03	689	0.29
	1992	2,364	1,423	0.60	94	0.04	1,517	0.64
	1993	2,432	1,426	0.59	135	0.06	1,561	0.64
	1994	2,342	1,234	0.53	130	0.06	1,364	0.58
	1995	1,773	523	0.29	88	0.05	611	0.34
	1996	2,607	1,301	0.50	131	0.05	1,432	0.55
	1997	2,494	868	0.35	115	0.05	983	0.39
	1998	2,488	1,044	0.42	125	0.05	1,169	0.47
	1999	2,177	514	0.24	68	0.03	582	0.27
	2000	2,619	949	0.36	93	0.04	1,042	0.40
	2001	2,298	555	0.24	119	0.05	674	0.29
	2002	2,566	836	0.33	66	0.03	902	0.35
	2003	2,601	650	0.25	174	0.07	824	0.32
	2004	2,565	569	0.22	74	0.03	643	0.25
	2005	2,637	598	0.23	112	0.04	710	0.27
	2006	2,579	767	0.30	99	0.04	866	0.34
	2007	2,574	586	0.23	125	0.05	711	0.28
	2008	2,558	1,685	0.66	135	0.05	1,820	0.71
	2009	2,755	445	0.16	235	0.09	680	0.25
	2010	2,208	1,077	0.49	158	0.07	1,235	0.56
	2011	2,336	1,520	0.65	274	0.12	1,794	0.77
Minimum		1,773	445	0.16	66	0.03	582	0.25
Maximum		2,940	1,953	0.82	274	0.13	2,042	0.89
Average (73-10)		2,464	1,109	0.45	132	0.05	1,241	0.51
2011 relative to (73-10) average		-5%	37%	44%	108%	117%	45%	52%
Average (84-10)		2,416	1,046	0.44	126	0.05	1,173	0.49
2011 relative to (84-10) average		-3%	45%	49%	117%	124%	53%	57%
Average (06-10)		2,535	912	0.37	150	0.06	1,062	0.43
2011 relative to (06-10) average		-8%	67%	77%	82%	98%	69%	80%

Table 9. Tags originally placed on Atlantic salmon in the Miramichi River system that were returned from the fishery at West Greenland in 2011.

Tag					Recapture			
Number	Date	Location	Fork length (mm)	Sex	Date	Location	Fork length (mm)	Weight (kg) Gutted/Whole
YY25646	23-Jul-10	Southwest Miramichi River, DFO Index trapnet at Millerton	730	F	12-Aug-11	Nuuk (1D)	817	4.66 (G)
YY30149	27-Sep-10	Northwest Miramichi River, DFO Index trapnet at Cassilis	778	F	26-Oct-11	Maniitsoq (1C)	*950	*9.20 (G)
B-47437	20-May-09	Cains River, MSA rotary screw trap	151	na	19-Sep-10	Itissaaq (1E)	*640	*4.00 (W)

* indicates estimates from fishers

Table 10. Estimated losses and estimated proportion of 2SW returns to SFA 16 in Gulf Region which were harvested in the West Greenland fishery, 1970-2010.

	Returns of 2SW salmon		West Greenland Catch of 1SW			
Assessment year	North America	SFA 16	Estimated total	Corrected to NA	Corrected catch to SFA 16	Proportion lost from SFA 16
1970	166,700	44,330				
1971	110,600	28,350	275,000			
1972	139,700	36,370	206,100	203,725	53,039	0.59
1973	146,400	33,510	259,400	152,683	34,948	0.51
1974	200,300	49,640	215,000	192,168	47,625	0.49
1975	166,700	32,640	270,500	159,276	31,186	0.49
1976	161,800	25,600	157,000	200,391	31,706	0.55
1977	218,200	61,540	198,600	116,308	32,803	0.35
1978	150,700	22,760	144,400	147,126	22,220	0.49
1979	74,950	7,904	197,300	106,974	11,281	0.59
1980	222,800	41,780	168,200	146,163	27,409	0.40
1981	153,600	15,210	224,200	124,606	12,339	0.45
1982	148,500	31,440	202,900	166,091	35,164	0.53
1983	118,700	22,380	37,330	150,312	28,340	0.56
1984	115,700	21,870	45,140	27,655	5,227	0.19
1985	132,600	26,180	137,800	33,441	6,602	0.20
1986	160,200	38,660	171,700	102,085	24,635	0.39
1987	125,900	22,400	172,100	127,198	22,631	0.50
1988	133,400	25,650	118,100	127,495	24,515	0.49
1989	113,200	16,310	60,690	87,491	12,606	0.44
1990	117,900	25,460	72,640	44,960	9,709	0.28
1991	108,500	26,260	110,700	53,813	13,024	0.33
1992	121,600	26,050	41,470	82,009	17,568	0.40
1993	109,100	37,830	2,629	30,722	10,653	0.22
1994	95,940	19,280	2,628	1,948	391	0.02
1995	126,100	31,420	26,680	1,947	485	0.02
1996	109,400	15,120	26,900	19,765	2,732	0.15
1997	88,060	11,380	18,140	19,928	2,575	0.18
1998	62,570	8,043	6,010	13,438	1,727	0.18
1999	66,650	8,858	8,964	4,452	592	0.06
2000	67,930	9,204	8,253	6,641	900	0.09
2001	77,910	16,050	11,970	6,114	1,260	0.07
2002	49,540	7,024	4,482	8,868	1,257	0.15
2003	75,020	13,380	4,833	3,320	592	0.04
2004	71,980	14,190	6,035	3,580	706	0.05
2005	73,690	14,970	5,813	4,471	908	0.06
2006	69,610	12,240	6,863	4,306	757	0.06
2007	66,310	12,030	9,204	5,084	922	0.07
2008	72,030	8,842	10,500	6,818	837	0.09
2009	85,990	14,340	9,279	7,779	1,297	0.08
2010	62,470	10,250	12,190	6,874	1,128	0.10

Table 11. The number of standard electrofishing sites sampled per Miramichi sub-basin during 1970 to 2011. Shaded areas indicate instances when three or fewer sites were sampled and omitted from analyses.

Year	Southwest	Renous	Northwest	Little Southwest
1970	28	5	4	0
1971	35	5	5	4
1972	35	4	5	4
1973	37	7	7	4
1974	37	9	23	4
1975	37	9	22	4
1976	31	7	21	4
1977	35	8	22	4
1978	36	8	22	4
1979	23	6	10	4
1980	22	5	9	4
1981	22	5	11	4
1982	35	8	21	7
1983	35	8	21	4
1984	35	8	21	4
1985	21	2	7	4
1986	17	2	4	4
1987	9	0	1	3
1988	9	2	1	3
1989	9	0	1	3
1990	9	0	1	3
1991	1	0	1	1
1992	8	0	1	3
1993	35	8	18	4
1994	29	9	27	12
1995	12	5	9	7
1996	15	8	14	7
1997	27	10	19	7
1998	27	10	17	8
1999	21	9	20	9
2000	26	9	20	8
2001	24	9	19	11
2002	25	10	19	10
2003	22	9	20	6
2004	25	9	19	8
2005	25	9	19	7
2006	25	9	20	7
2007	30	11	16	10
2008	26	10	16	9
2009	30	11	16	9
2010	22	9	18	9
2011	15	6	15	8

Table 12. Estimates of smolts and subsequent return rates as 1SW and 2SW salmon in the Miramichi watershed. Smolt estimates for the NW Miramichi River in 1998-2000 were from Chaput et al. (2002), between 2001 and 2011 from NB Wildlife Trust Fund (WTF) Completion Reports prepared by DFO or the Miramichi Salmon Association (unpublished data). Smolt estimates for the Little Southwest Miramichi were obtained from WTF completion reports submitted by the Northumberland Salmon Protection Association (unpublished data). Smolt estimates for the SW Miramichi were from WTF completion reports prepared by DFO or the Miramichi Salmon Association (unpublished data). Numbers in italics are unreliable estimates due to sampling issues.

	Smolt		Smolts per 100 m²		% return	
Year	Estimate	95% C.I.	Estimate	95% C.I.	1SW	2SW
Little Southwest						
2005	*46,330*	*32,710 - 68,050*				
2006	87,520	41,760 - 665,300	1.0	0.5 - 7.6		
2007	138,200	106,000 - 185,500	1.6	1.2 - 2.1		
2008	124,100	96,320 - 164,900	1.4	1.1 - 1.9		
2009	85,000	66,000 - 112,00	1.0	0.8 - 1.3		
2010	46,500	28,500 - 82,500	0.5	0.3 - 0.9		
2011	67,900	49,900 - 104,500	0.9	0.6 - 1.3		
Mean	**85,079**		**1.1**			
Northwest						
1999	390,500	315,500 - 506,000	2.3	1.9 - 3.0	2.95%	1.21%
2000	162,000	118,000 - 256,000	1.0	0.7 - 1.5	4.89%	0.47%
2001	220,000	169,000 - 310,000	1.3	1.0 - 1.8	6.59%	0.64%
2002	241,000	198,000 - 306,000	1.4	1.2 - 1.8	2.42%	0.73%
2003	286,000	224,500 - 388,000	1.7	1.3 - 2.3	4.10%	0.87%
2004	368,000	290,000 - 496,000	2.2	1.7 - 3.0	2.56%	0.49%
2005	151,200	*86,000 - 216,000*	*0.9*	*0.5 - 1.3*	3.62%	1.15%
2006	435,000	*255,000 - 1,230,000*	*2.6*	*1.5 - 7.3*	1.39%	0.18%
2011	768,000	576,000 - 1,137,000	4.6	3.4 - 6.8		
Mean	**335,744**		**2.0**		**3.57%**	**0.72%**
Southwest						
2001	306,300	290,000 - 464,000	1.0	0.8 - 1.3	8.61%	3.30%
2002	711,400	498,000 - 798,000	1.7	1.4 - 2.3	3.05%	1.43%
2003	485,000	393,000 - 615,000	1.3	1.1 - 1.7	6.79%	2.00%
2004	1,167,000	969,000 - 1,470,000	3.2	2.6 - 3.5	1.77%	0.77%
2005						
2006	1,332,000	983,000 - 1,809,000	3.8	2.8 - 5.1	1.48%	0.49%
2007	1,344,000	1,120,000 - 1,668,000	3.8	3.2 - 4.7	1.62%	0.76%
2008	901,500	698,000 - 1,262,000	2.5	2.0 - 3.6	0.97%	0.74%
2009	1,035,000	807,000 - 1,441,000	2.9	2.3 - 4.1	3.29%	2.23%
2010	2,165,000	1,745,000 - 2,725,000	6.1	4.9 - 7.7	1.46%	
Mean	**1,049,689**		**2.9**		**3.22%**	**1.46%**
Miramichi						
2001	526,300		1.1		7.94%	2.25%
2002	952,400		1.6		2.97%	1.28%
2003	771,000		1.6		5.90%	1.63%
2004	1,535,000		2.9		1.99%	0.73%
2005						
2006	1,767,000		3.4		1.47%	0.42%
Mean	**1,110,340**		**2.1**		**4.05%**	**1.26%**

Table 13. Linear regression analyses and their respective r-square values for possible development in a framework of abundance indicators for adult salmon in the Miramichi watershed.

Time series	Variable 1	Variable 2	r^2
Trapnet catches by August 31			
1998 - 2011	NW Cassilis small salmon catch	Northwest small salmon estimate	0.83
1998 - 2011	NW Cassilis large salmon catch	Northwest large salmon estimate	0.23
1998 - 2011	SW Millerton small salmon catch	Southwest small salmon estimate	0.73
1998 - 2011	SW Millerton large salmon catch	Southwest large salmon estimate	0.32
1998 - 2011	NW Cassilis + SW Millerton small salmon catch	Miramichi small salmon estimate	0.82
1998 - 2011	NW Cassilis + SW Millerton large salmon catch	Northwest large salmon estimate	0.40
Trapnet catches total for season			
1998 - 2011	NW Cassilis small salmon catch	Northwest small salmon estimate	0.86
1998 - 2011	NW Cassilis large salmon catch	Northwest large salmon estimate	0.73
1998 - 2011	SW Millerton small salmon catch	Southwest small salmon estimate	0.59
1998 - 2011	SW Millerton large salmon catch	Southwest large salmon estimate	0.12
1998 - 2011	NW Cassilis + SW Millerton small salmon catch	Miramichi small salmon estimate	0.77
1998 - 2011	NW Cassilis + SW Millerton large salmon catch	Miramichi large salmon estimate	0.23
Barrier counts			
1998 - 2011	NW Barrier small salmon count	Northwest small salmon estimate	0.15
1998 - 2011	NW Barrier large salmon count	Northwest large salmon estimate	0.12
1998 - 2011	Dungarvon Barrier small salmon count	Southwest small salmon estimate	0.34
1998 - 2011	Dungarvon Barrier large salmon count	Southwest large salmon estimate	0.44
1998 - 2009	Juniper Barrier small salmon count	Southwest small salmon estimate	0.69
1998 - 2009	Juniper Barrier large salmon count	Southwest large salmon estimate	0.50
1998 - 2009	Dungarvon + Juniper Barrier small salmon count	Southwest small salmon estimate	0.05
1998 - 2009	Dungarvon + Juniper Barrier large salmon count	Southwest large salmon estimate	0.71
1998 - 2009	Dungarvon + Juniper + NW Barrier small salmon count	Miramichi small salmon estimate	0.40
1998 - 2009	Dungarvon + Juniper + NW Barrier large salmon count	Miramichi large salmon estimate	0.51
Northwest crown reserve angling catches			
1998 - 2011	NW crown reserve small salmon catch	Northwest small salmon estimate	0.11
1998 - 2011	NW crown reserve large salmon catch	Northwest large salmon estimate	0.01
1998 - 2011	NW crown reserve small salmon catch	Southwest small salmon estimate	0.16
1998 - 2011	NW crown reserve large salmon catch	Southwest large salmon estimate	0.52
1998 - 2011	NW crown reserve small salmon catch	Miramichi small salmon estimate	0.16
1998 - 2011	NW crown reserve large salmon catch	Miramichi large salmon estimate	0.41

FIGURES

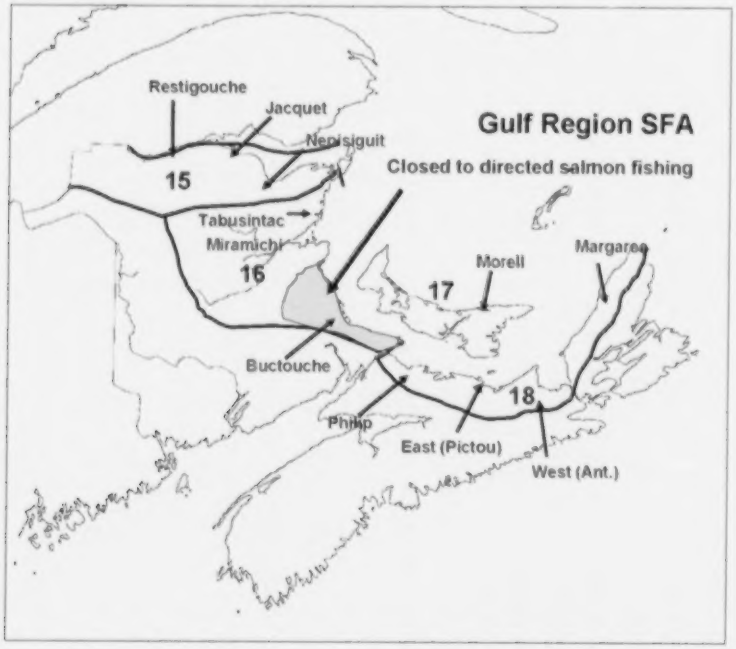


Figure 1. DFO Gulf region's Salmon Fishing Areas 15 to 18 and the locations of rivers referred to in the text.

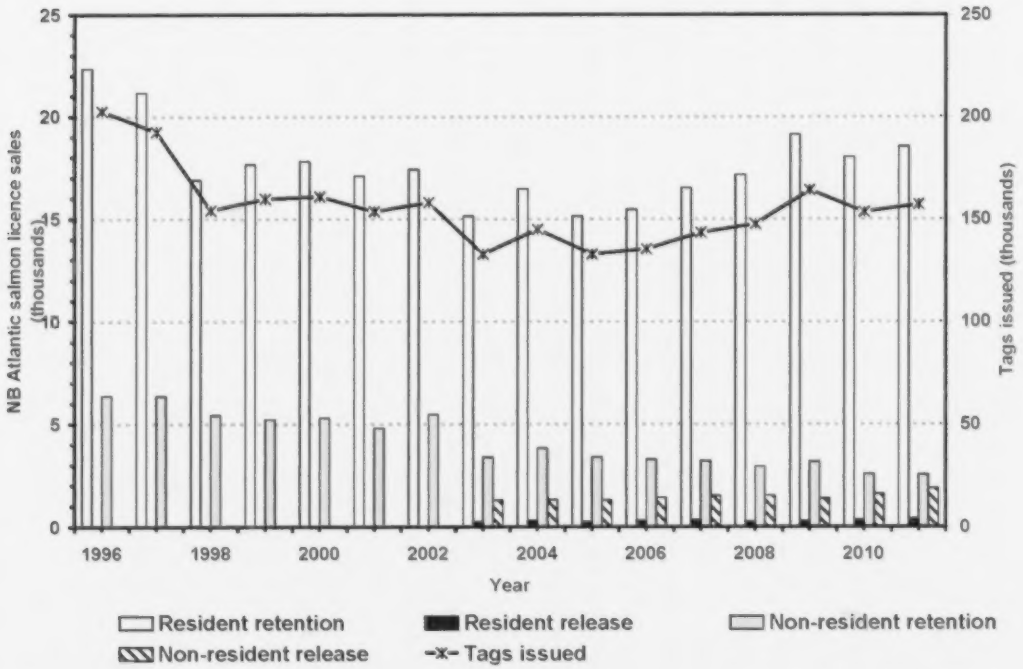


Figure 2. Angling licenses sold and tags issued for Atlantic salmon in New Brunswick 1996 to 2011 (information provided by C. Connell NB DNR).

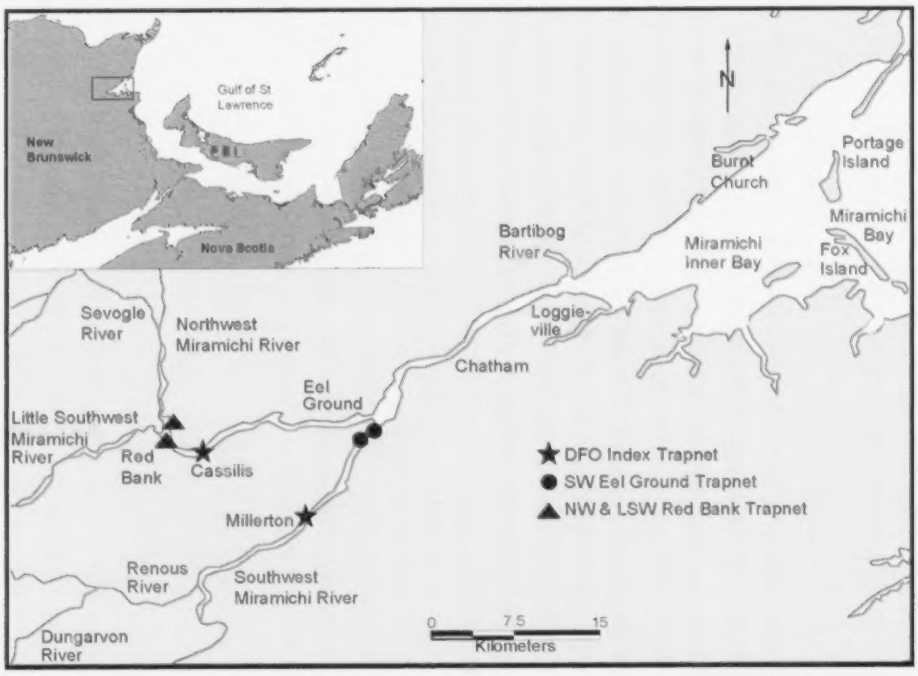


Figure 3. Location of trapnets in the Miramichi estuary where salmon are tagged and recaptured.

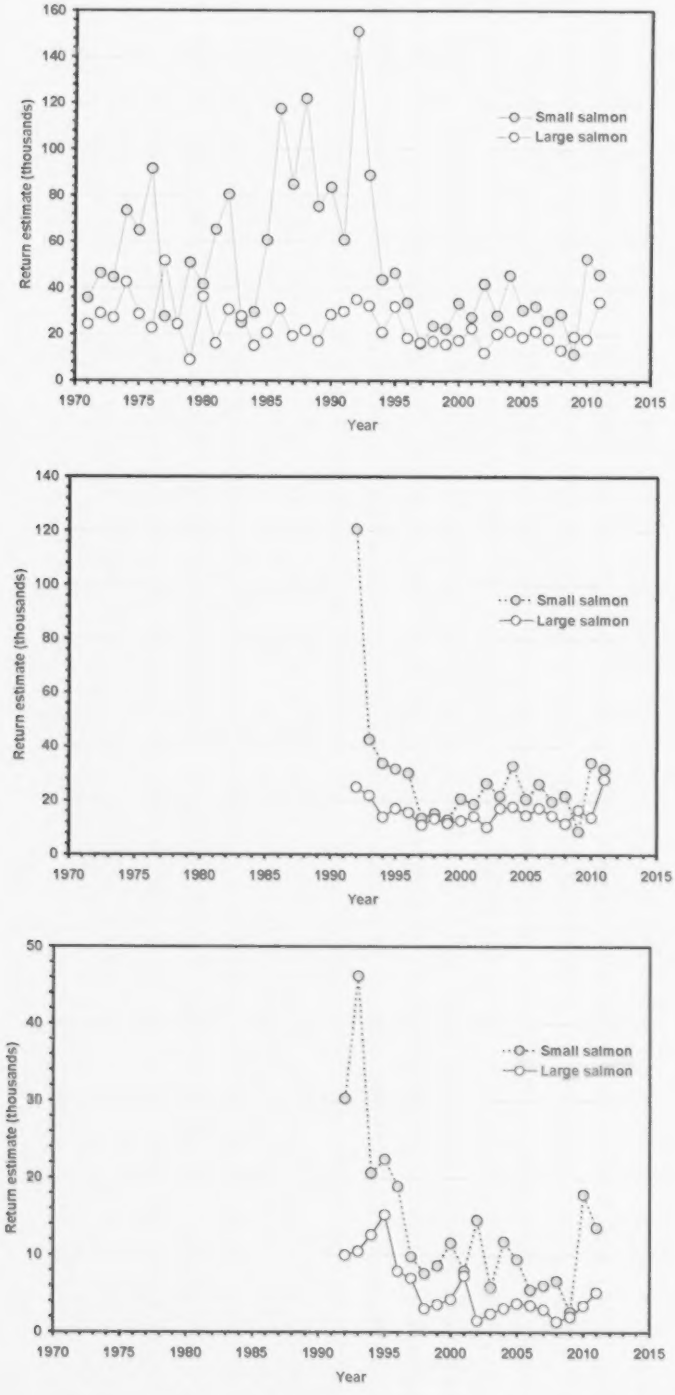


Figure 4. Median estimates of large and small salmon returns for the Miramichi River 1970 to 2011 (upper panel), the Southwest Miramichi River 1992 to 2011 (middle panel), and the Northwest Miramichi River 1992 to 2011 (lower panel).

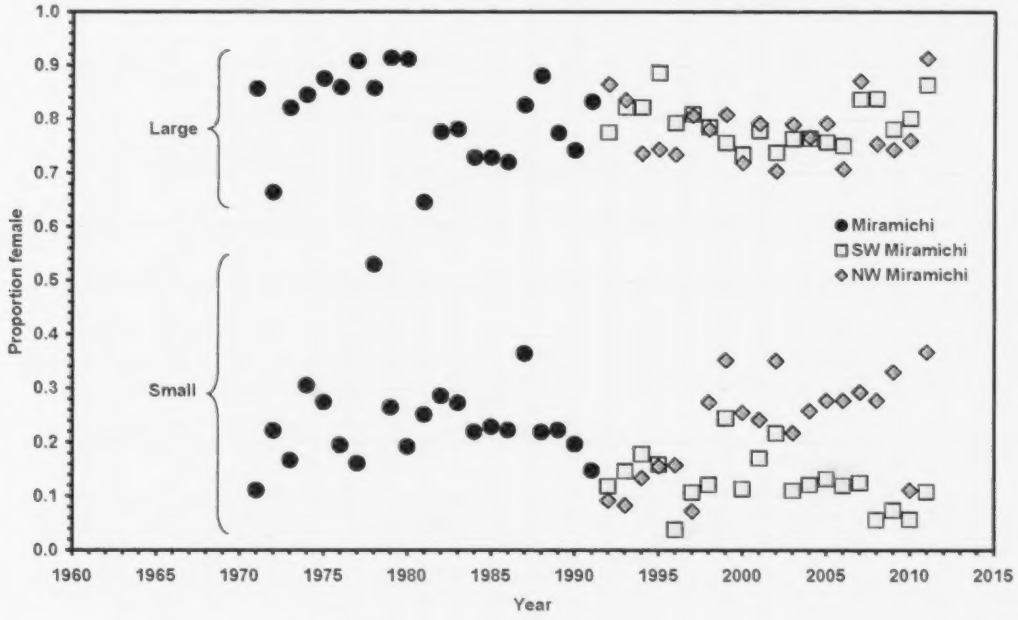


Figure 5. Proportion of female large and small salmon from the Miramichi River (1970 to 1991) and the Northwest and Southwest Miramichi rivers (1992 to 2011).

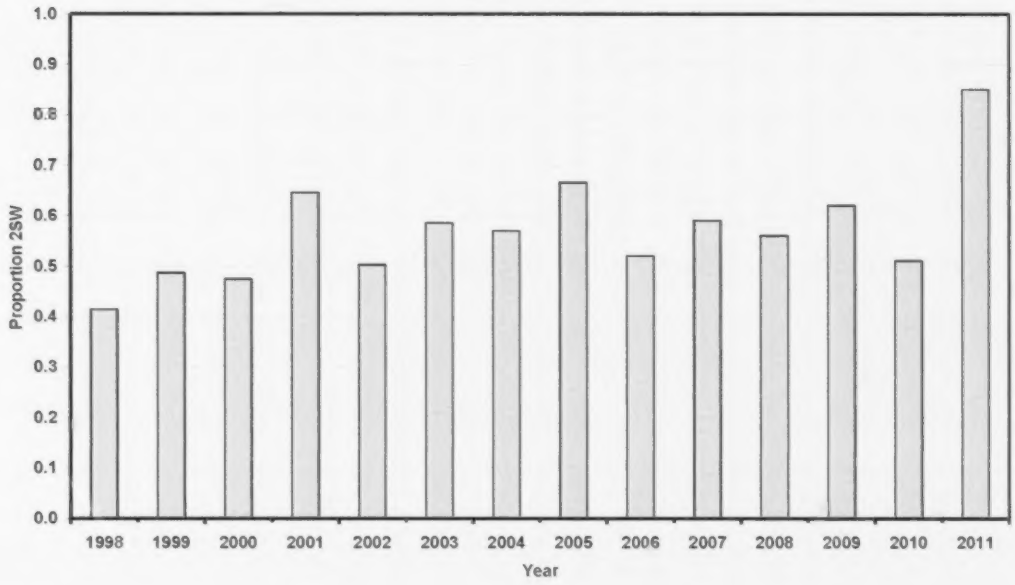


Figure 6. Proportion 2SW maiden salmon in the large salmon category (≥ 63cm fork length) sampled at DFO index trapnets on the Northwest and Southwest Miramichi rivers, 1998 to 2011.

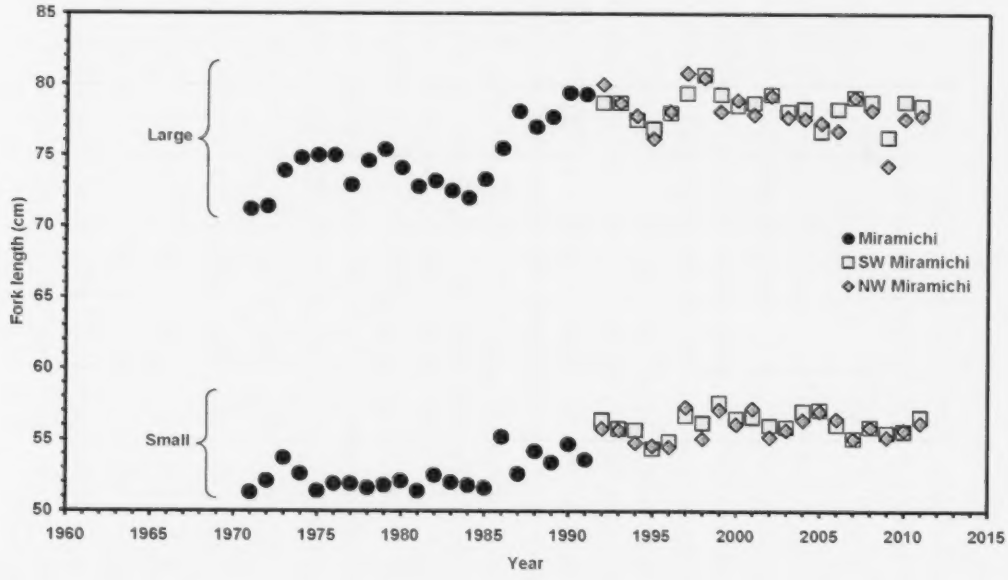


Figure 7. Mean fork length (mm) of small salmon and large salmon from the Miramichi River and the two main branches, 1970 to 2011.

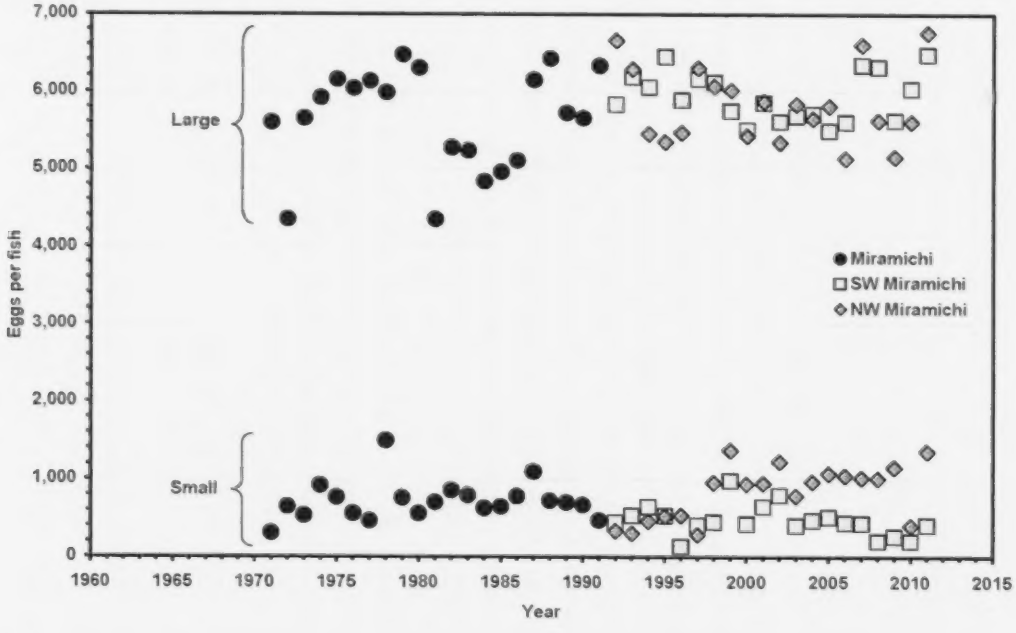


Figure 8. Number of eggs per large and small salmon from the Miramichi (1970-1991) and the Northwest and Southwest Miramichi rivers (1992 to 2011). Eggs were calculated from the annual average biological characteristics of small and large salmon in the Miramichi.

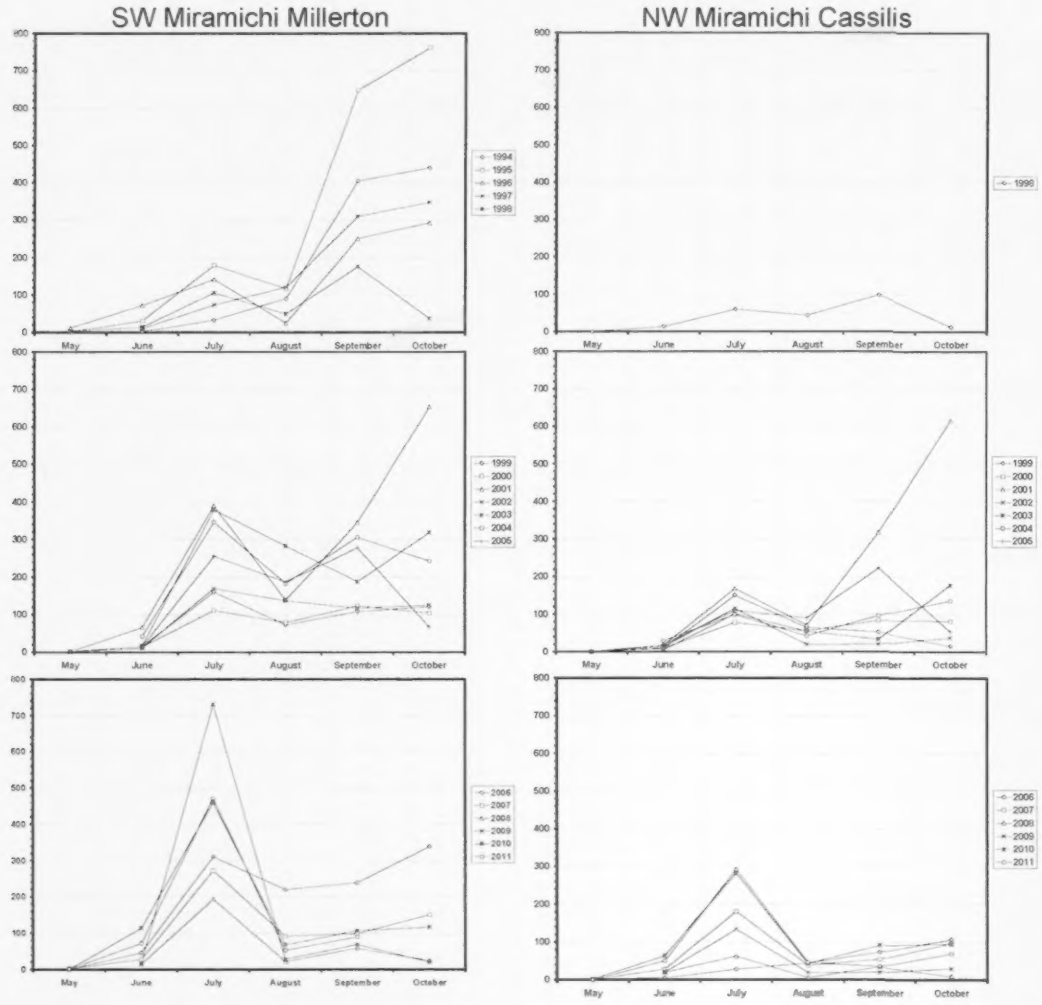


Figure 9. Run timing of large salmon to DFO Index trapnets on the Southwest Miramichi (left panels) and Northwest Miramichi (right panels) rivers, 1994 to 2011.

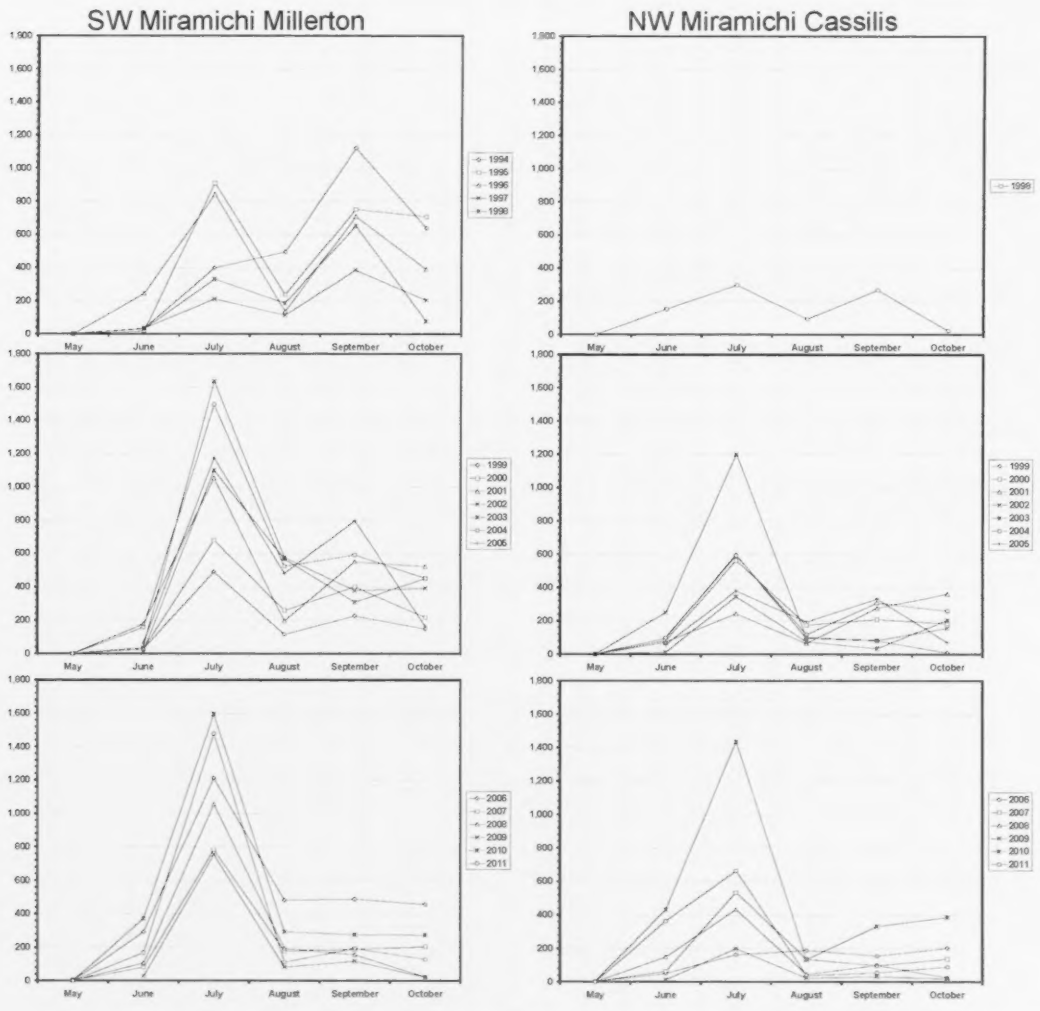


Figure 10. Run timing of small salmon to DFO Index trapnets on the Southwest Miramichi (left panels) and Northwest Miramichi (right panels) rivers, 1994 to 2011.

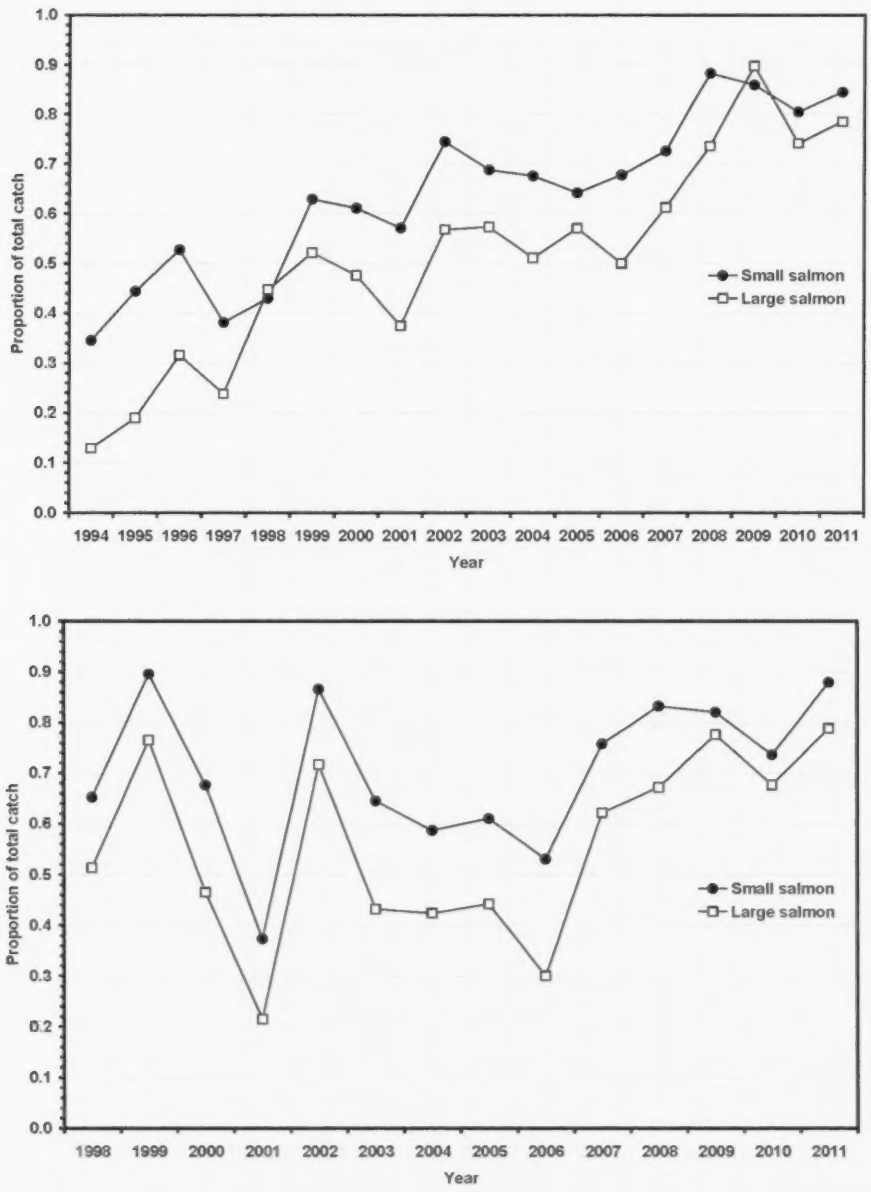


Figure 11. Proportion of large and small salmon catches by August 31 at DFO Index trapnets at Millerton on the Southwest Miramichi River (upper panel) and at Cassilis on the Northwest Miramichi River (lower panel) for 1998 to 2011.

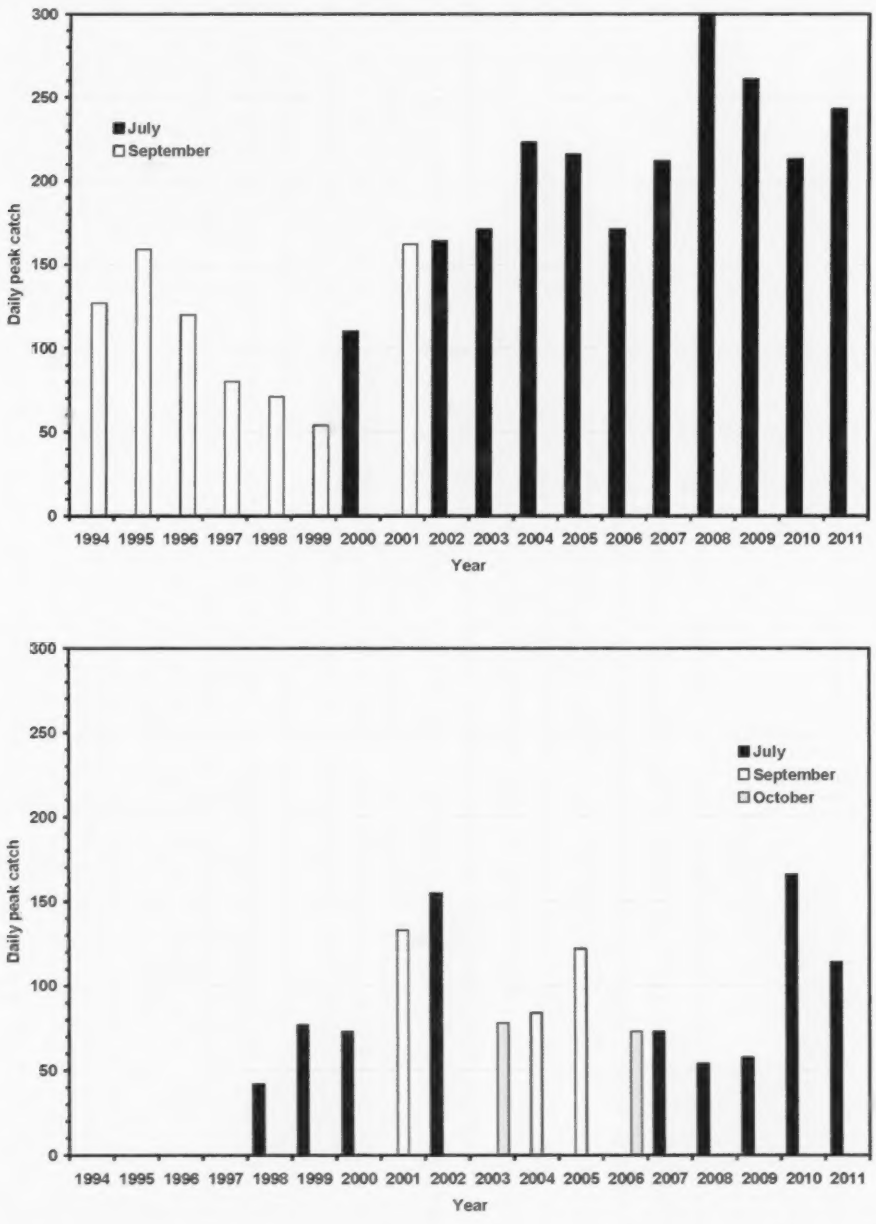


Figure 12. Single-day peak catch of small and large salmon combined at DFO Index trapnets at Millerton on the Southwest Miramichi River (upper panel) and at Cassilis on the Northwest Miramichi River (lower panel) for the time series of operation, 1994 to 2011.

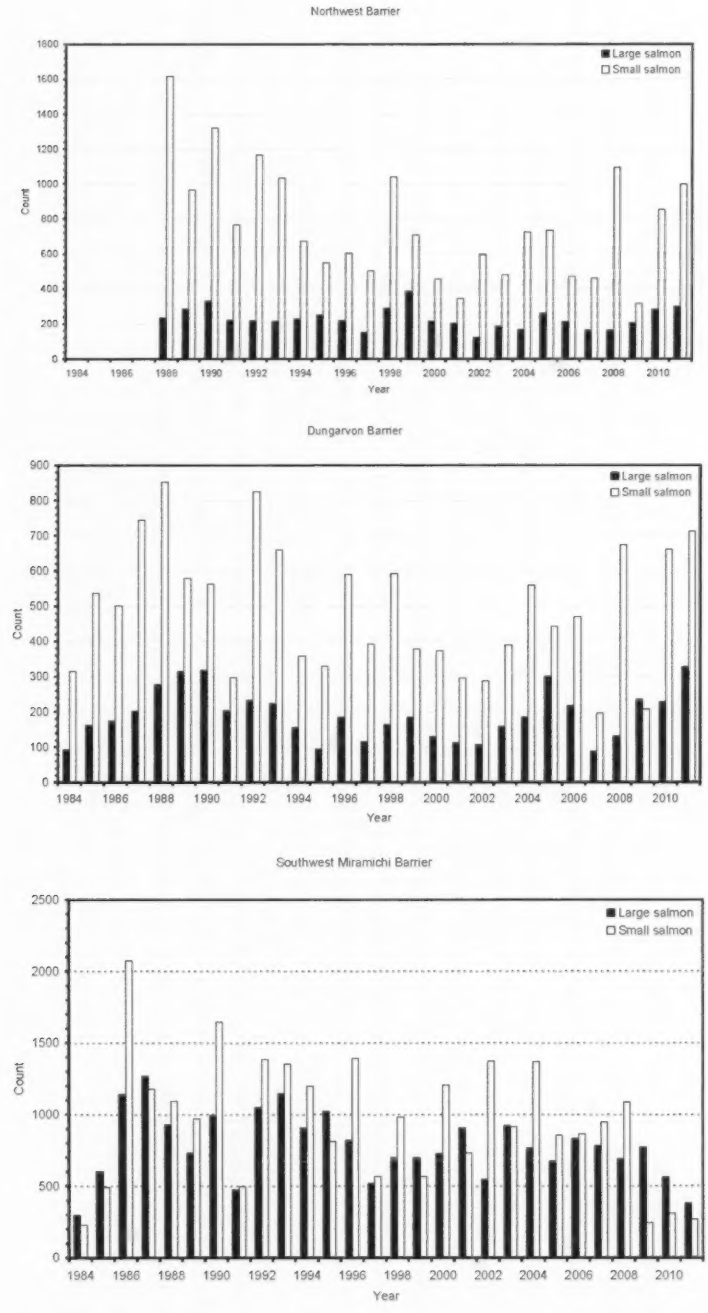


Figure 13. Counts of large and small Atlantic salmon at the headwater protection barrier on the Northwest Miramichi River (upper panel), the Dungarvon River (middle panel), and the north branch of the Southwest Miramichi River near Juniper (lower panel) between 1984 and 2011. Counts at Juniper were incomplete in 2010 and 2011.

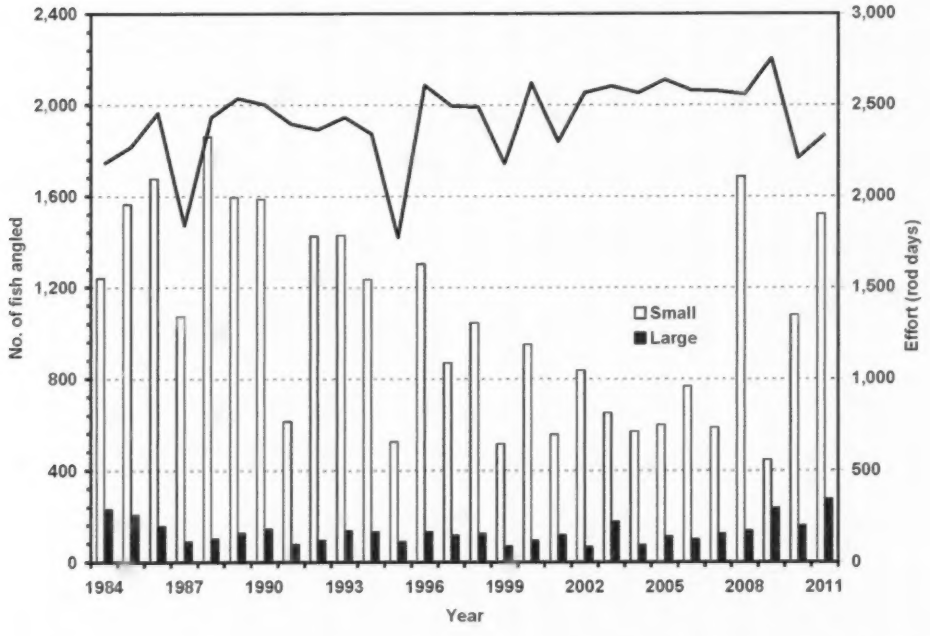


Figure 14. Effort and angling catches of large and small Atlantic salmon from the provincial Regular Crown Reserve stretches of the Northwest Miramichi River, 1984 to 2011 (Dubee et al. 2011).

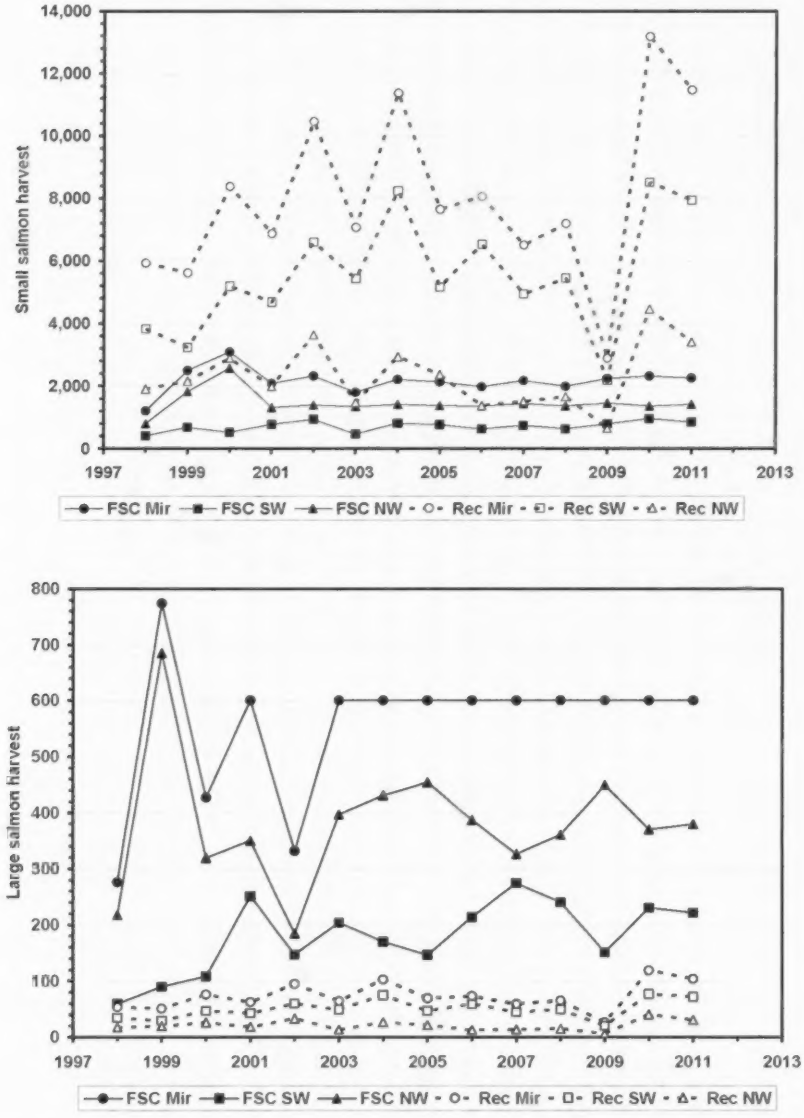


Figure 15. Assumed and estimated levels of small (upper panel) and large (lower panel) salmon harvests in the aboriginal fisheries for food, social and ceremonial purposes (FSC) and recreational (Rec) fisheries of the Miramichi River, Southwest Miramichi, and Northwest Miramichi rivers, 1998 to 2011.

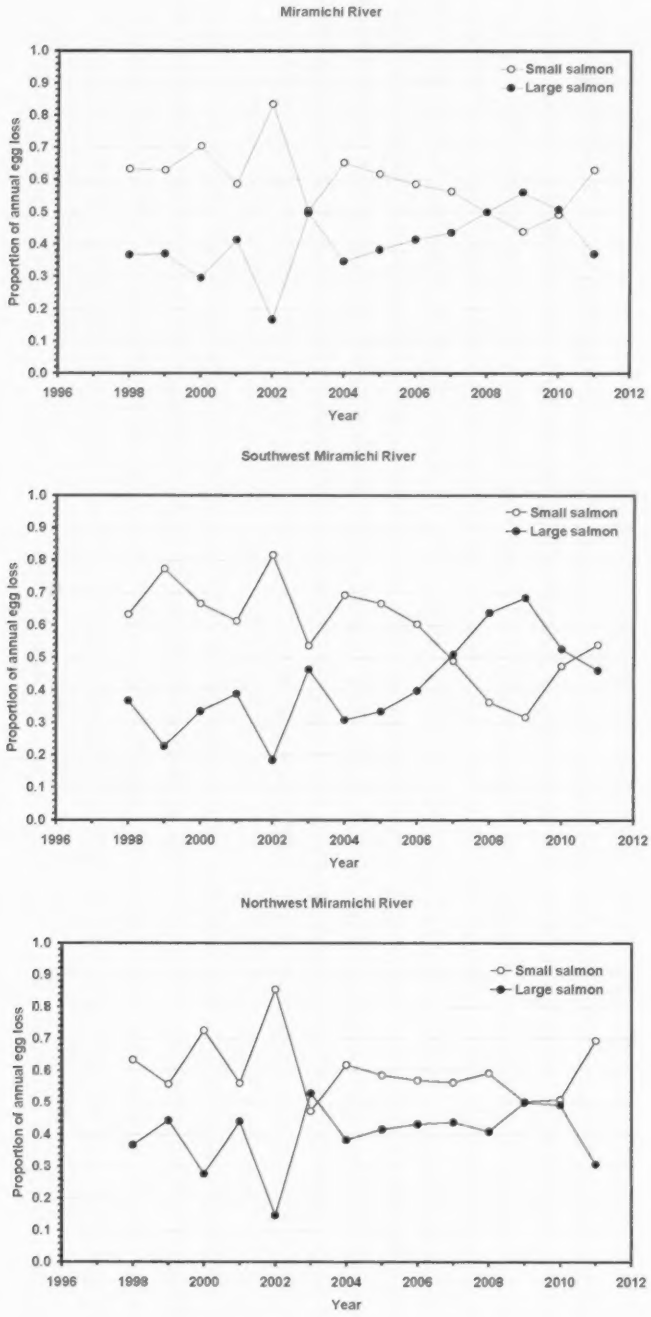


Figure 16. Proportion of annual egg loss by salmon size group in the Miramichi River (upper panel), Southwest Miramichi River (middle panel), and Northwest Miramichi River (lower panel) in 1998 to 2011.

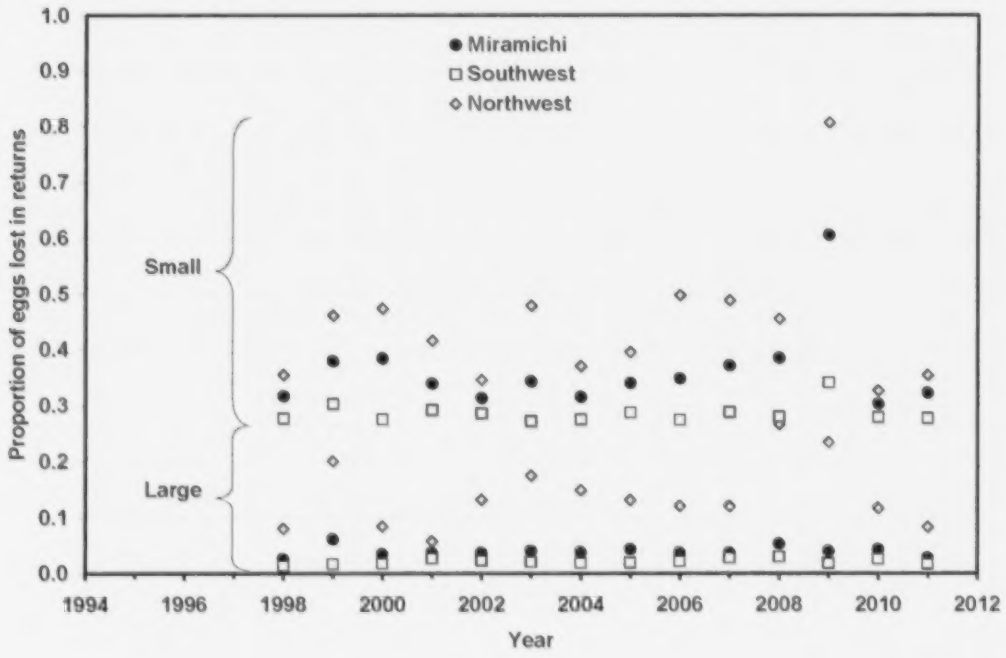


Figure 17. Proportion of eggs lost in the returns of small and large salmon to the Miramichi River and its two main branches, 1998 to 2011.

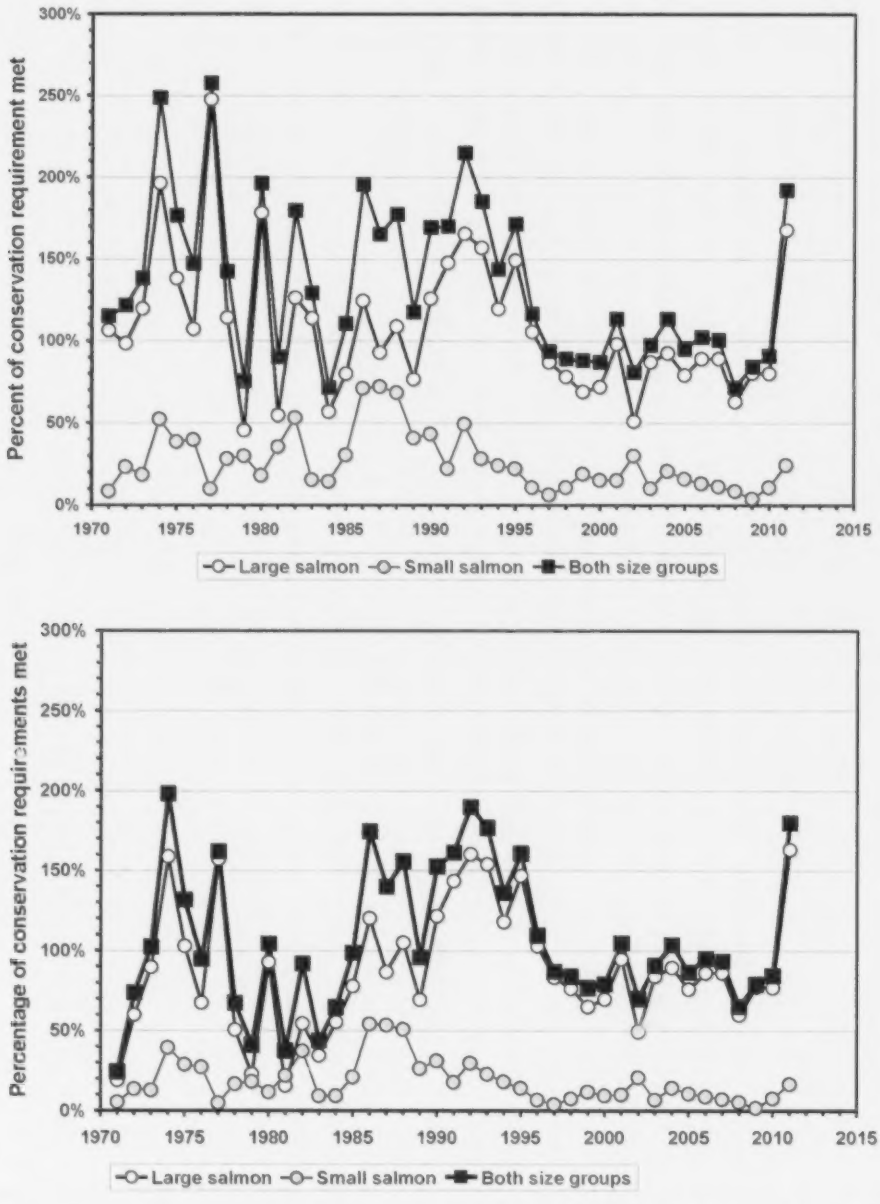


Figure 18. The number of eggs relative to the conservation requirement in the returns (upper panel) and escapement (lower panel) of Atlantic salmon to the Miramichi River overall, 1970 to 2011.

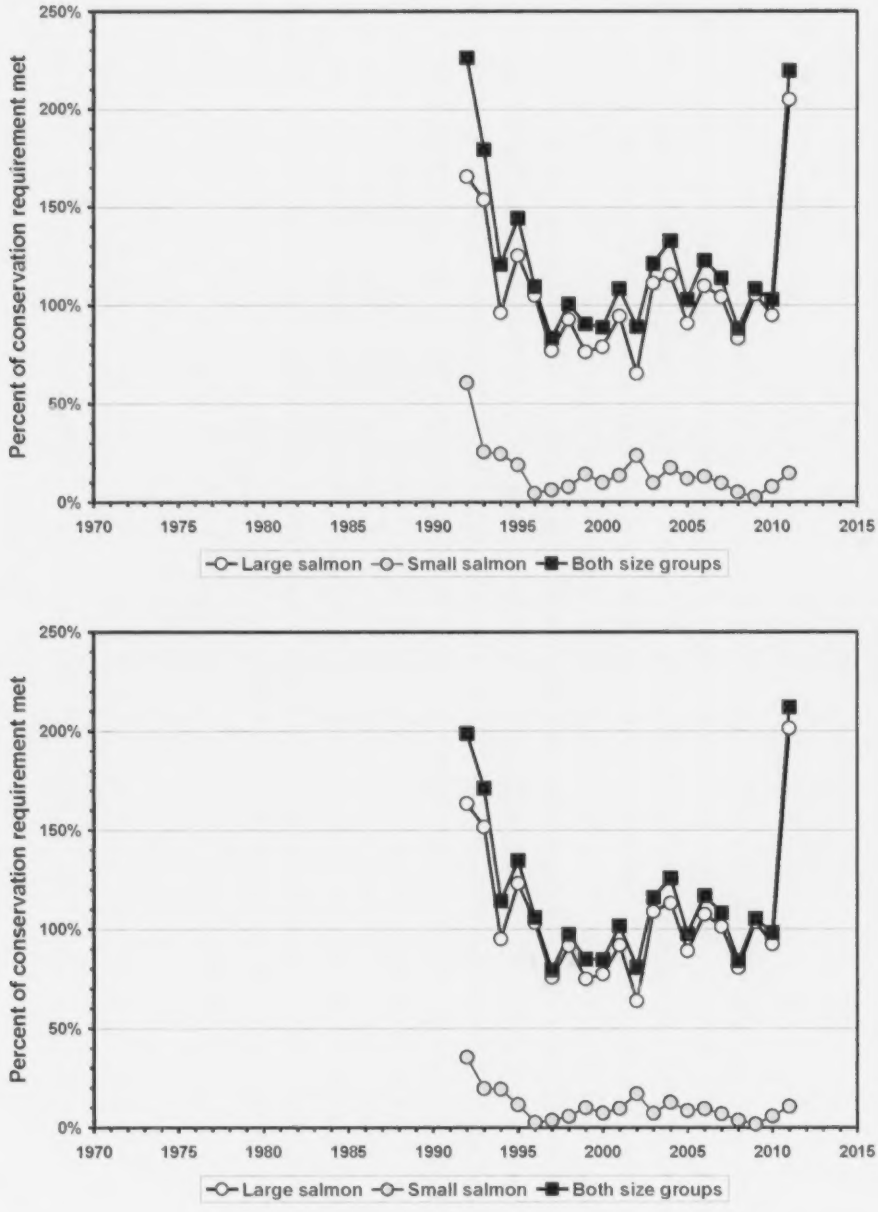
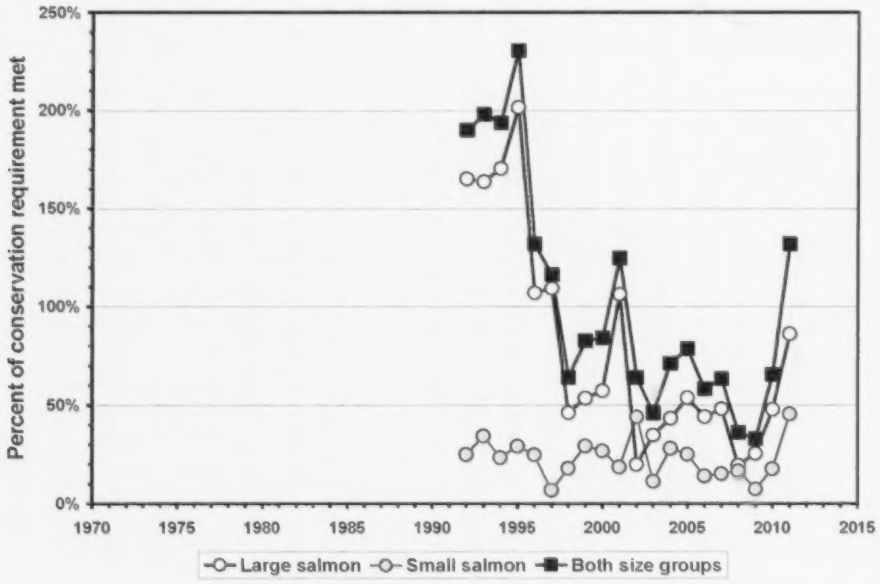


Figure 19. The number of eggs relative to the conservation requirement in the returns (upper panel) and escapement (lower panel) of Atlantic salmon to the Southwest Miramichi River, 1992 to 2011.



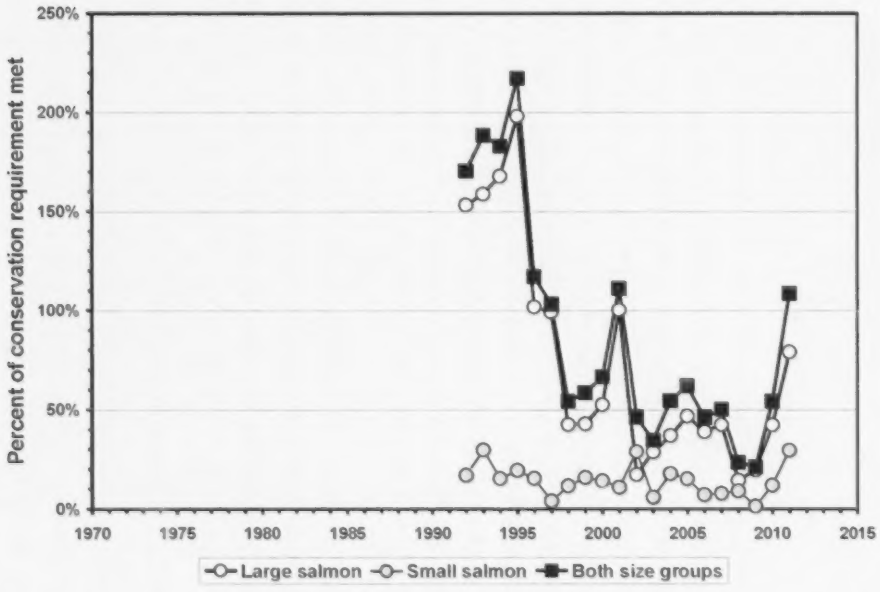


Figure 20. The number of eggs relative to the conservation requirement in the returns (upper panel) and escapement (lower panel) of Atlantic salmon to the Northwest Miramichi River, 1992 to 2011.

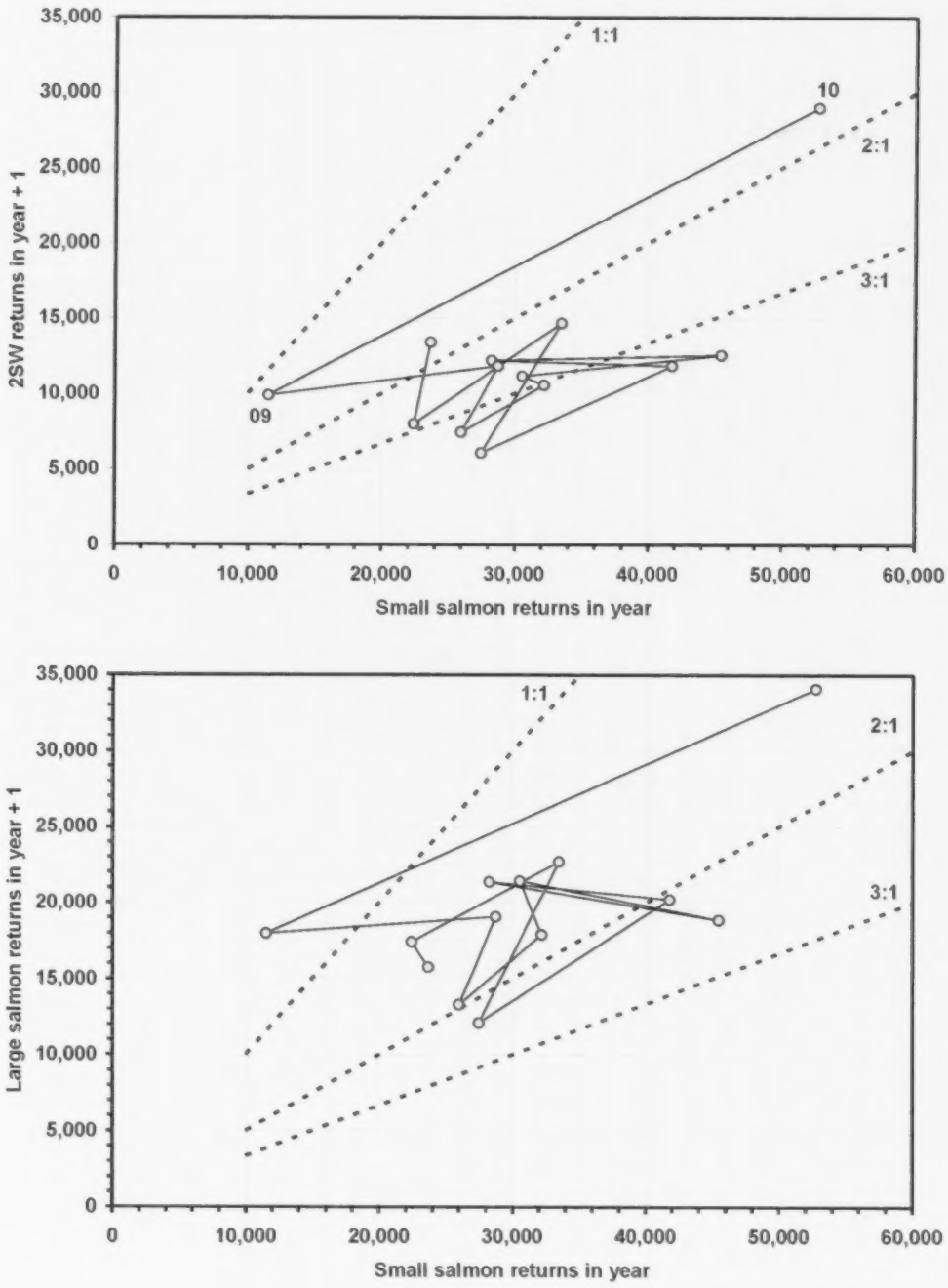


Figure 21. Relationship between small salmon returns in a given year and 2SW returns the following year (upper panel) and large salmon returns in the following year (lower panel) for the small salmon return years between 1998 and 2010.

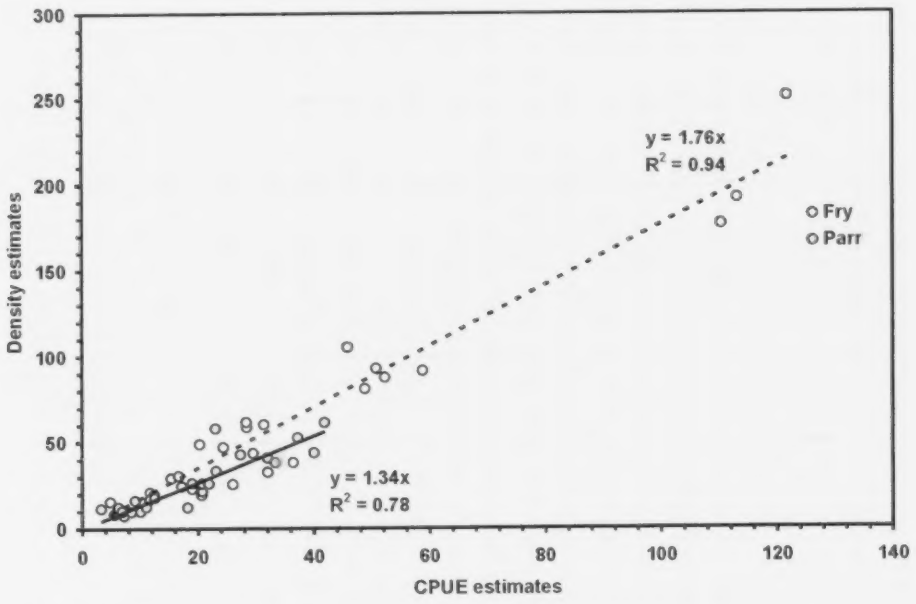


Figure 22. Linear relationship between estimates of density and abundance for juvenile salmon at closed sites in the Miramichi watershed 2006-2011. Densities of fry and parr at open sites in 2011 were predicted from these relationships.

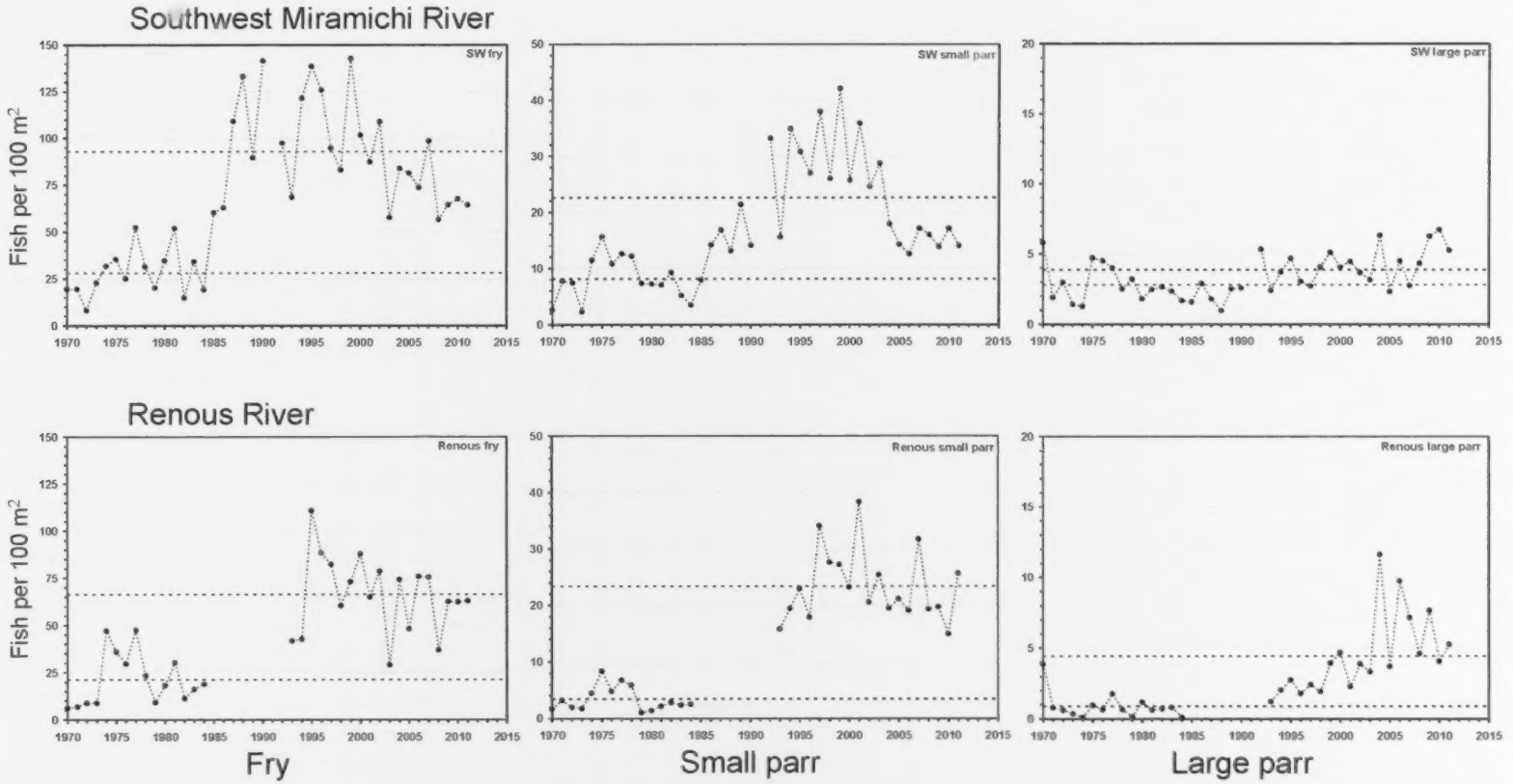


Figure 23. Average abundance of juvenile Atlantic salmon by size group in the Southwest Miramichi and Renous rivers, 1970 to 2011. The bottom horizontal line depicts average density of fry (1970-1984), small parr (1970-1985), and large parr (1970-1986) while the top horizontal line depicts average density of fry (1985-2011), small parr (1986-2011), and large parr (1987-2011) after significant management changes were implemented to the commercial and recreational salmon fisheries in 1984.

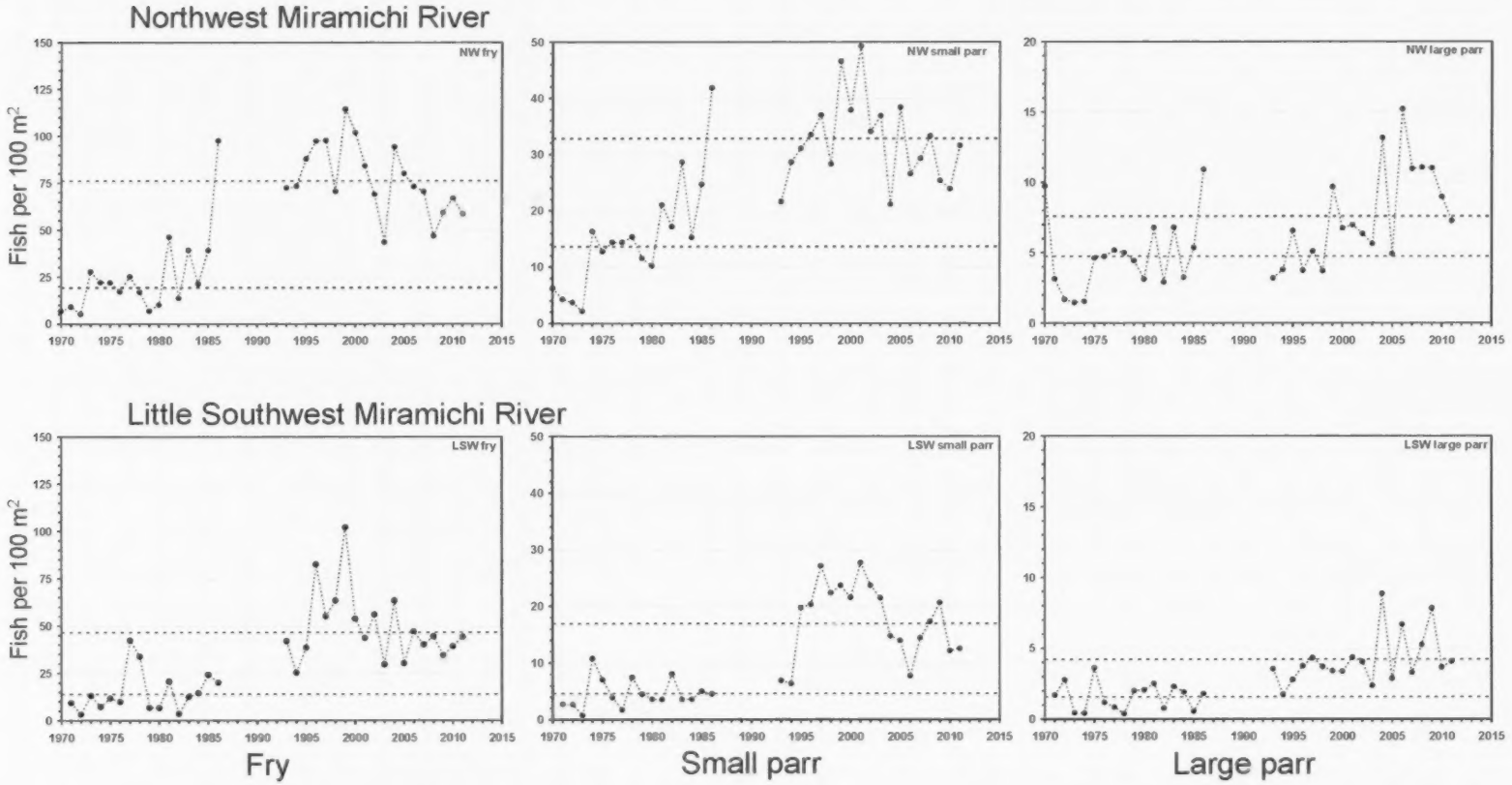


Figure 24. Average abundance of juvenile Atlantic salmon by size group in the Northwest and Little Southwest Miramichi rivers, 1970 to 2011. The bottom horizontal line depicts average density of fry (1970-1984), small parr (1970-1985), and large parr (1970-1986) while the top horizontal line depicts average density of fry (1985-2011), small parr (1986-2011), and large parr (1987-2011) after significant management changes were implemented to the commercial and recreational salmon fisheries in 1984.

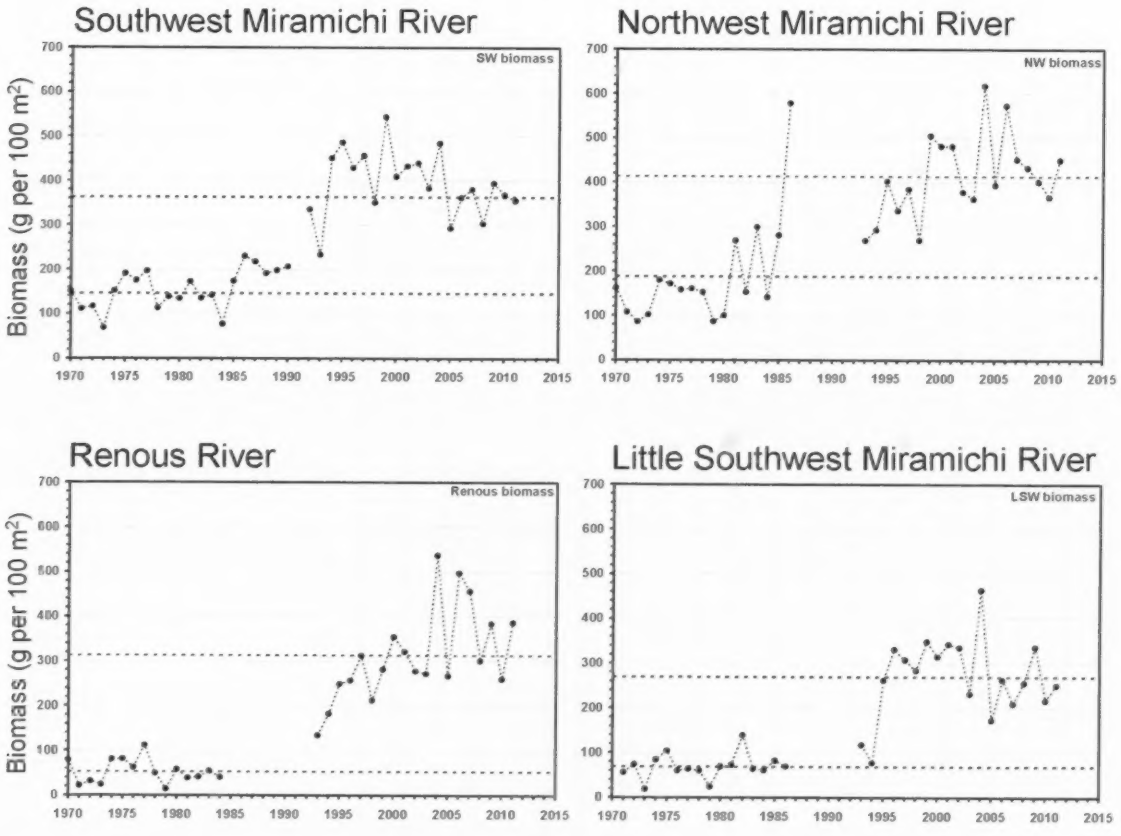


Figure 25. Total biomass of juvenile Atlantic salmon in the four major rivers of the Miramichi watershed, 1970 to 2011. Horizontal lines depict average biomass for the years 1970-1986 (bottom) and years 1987-2011 (top).

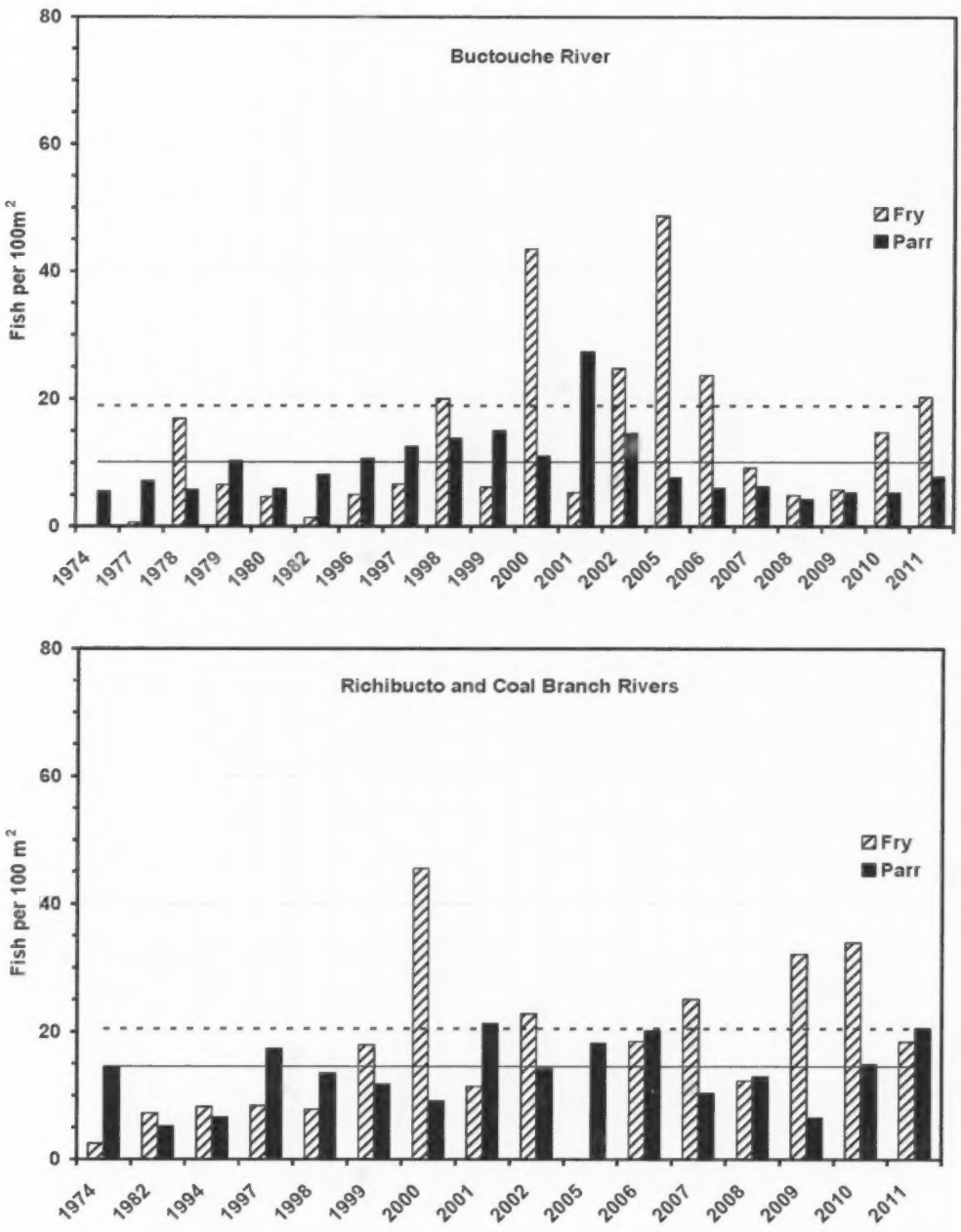


Figure 26. Average juvenile salmon densities by size group in the two largest rivers of southeastern New Brunswick, for all years when surveys were conducted (1974 to 2011). The horizontal lines represent averages for fry (hatched) and parr (solid) in their respective rivers after the aboriginal and recreational fisheries were closed in 1998.

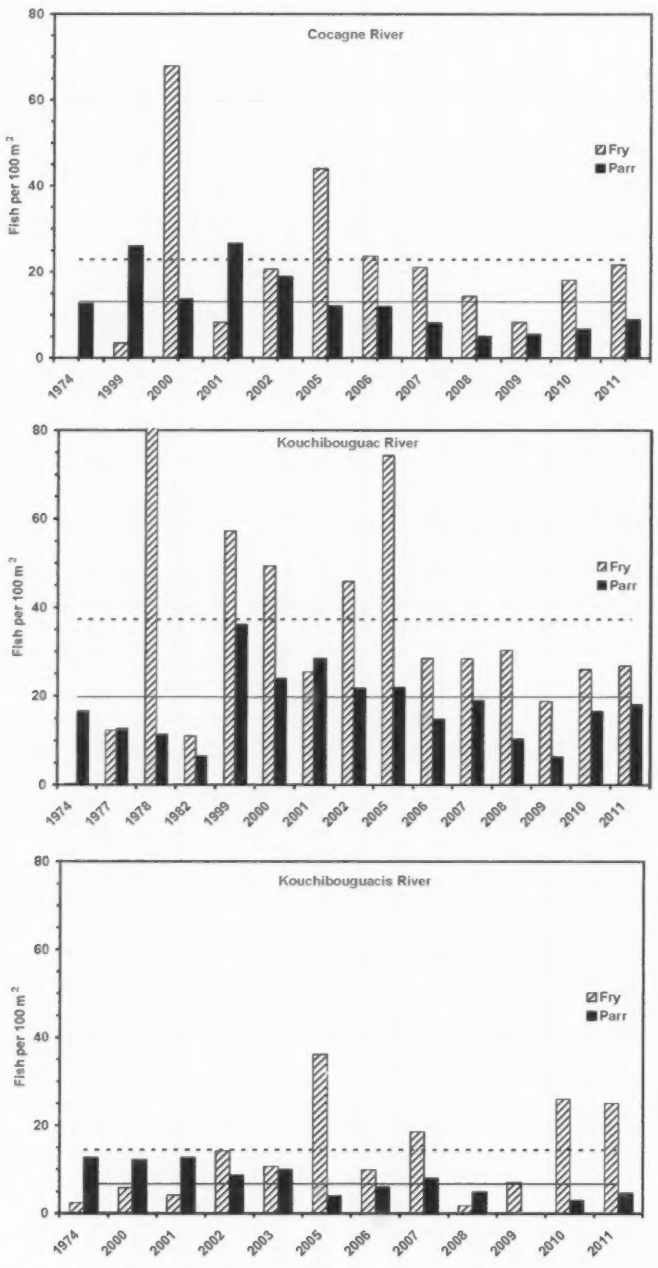


Figure 27. Average juvenile salmon densities by size group in three smaller rivers of southeastern New Brunswick, for all years when surveys were conducted (1974 to 2011). The horizontal lines represent averages for fry (hatched) and parr (solid) in their respective rivers after the aboriginal and recreational fisheries were closed in 1998. The 1978 value for fry density in the Kouchibouguac River was 116 fish.

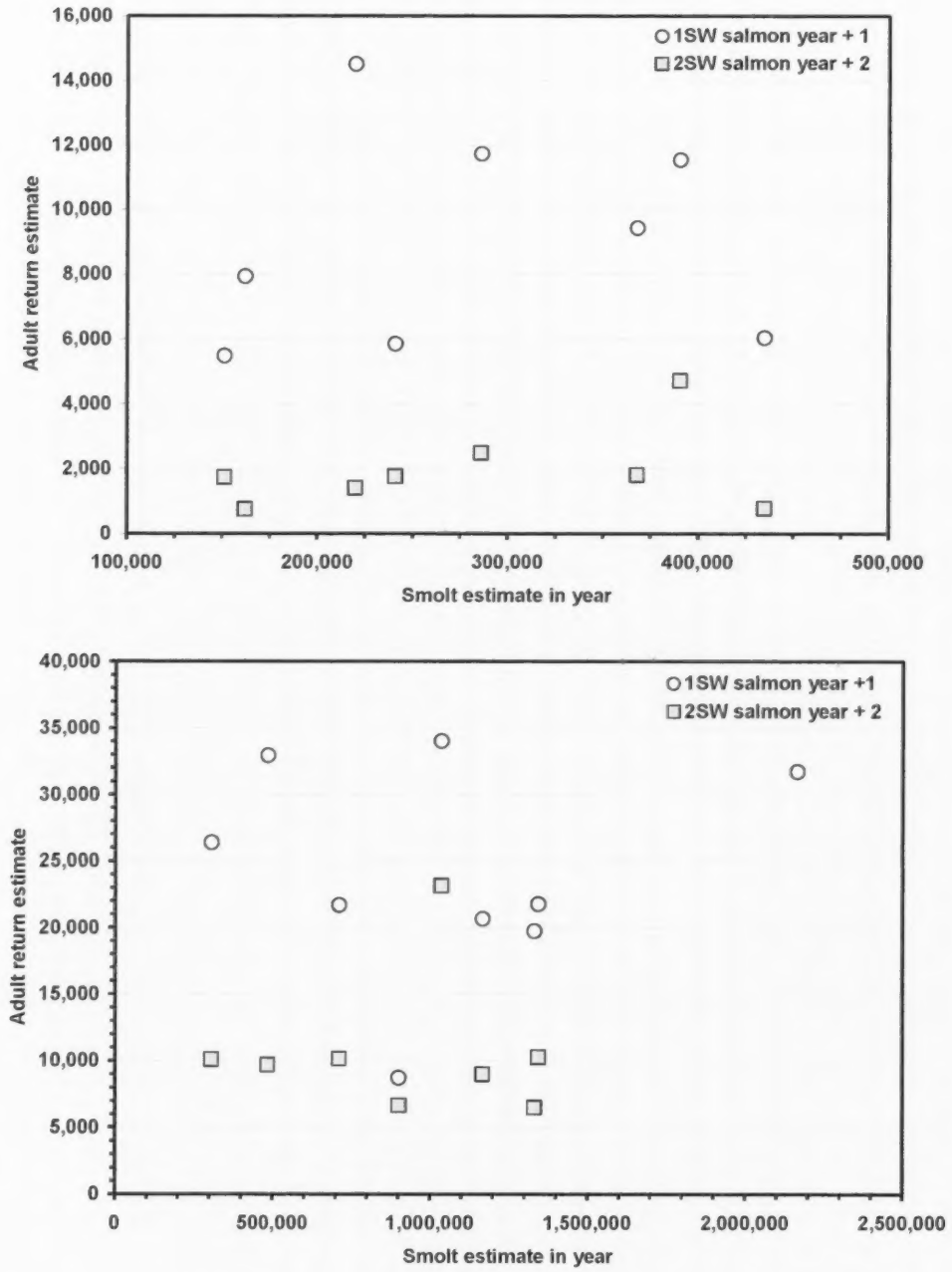


Figure 28. Returns of 1SW and 2SW salmon relative to their abundance as smolts on the Northwest 1999 to 2006 (upper panel) and Southwest 2001 to 2010 (lower panel) Miramichi rivers.

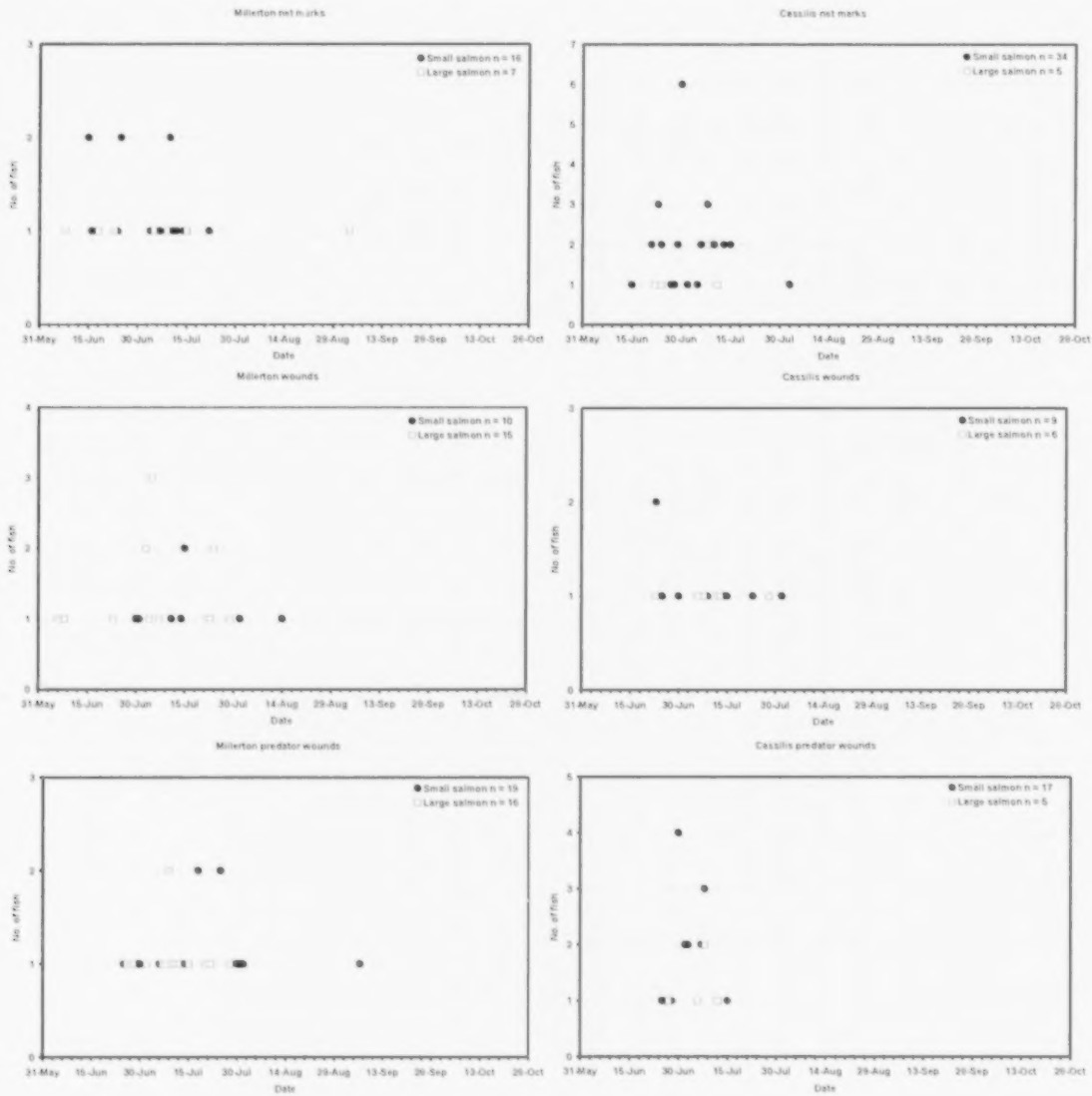


Figure 29. Observations of small and large salmon with net marks (upper panel), wounds (middle panel), and predator wounds (lower panel) at DFO index trapnets on the Southwest Miramichi River at Millerton (left panels) and Northwest Miramichi River at Cassilis (right panels) in 2011.